5

Biostratigraphy

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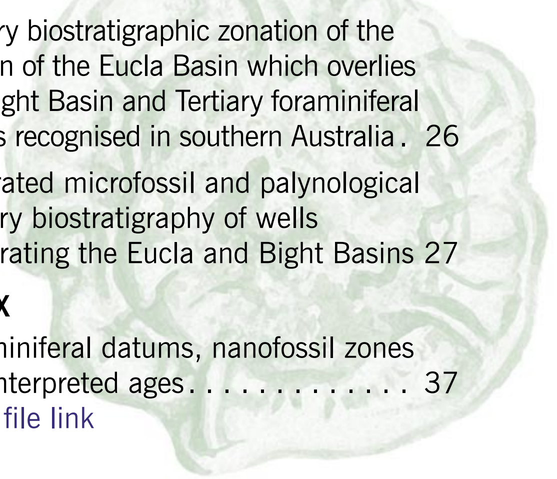

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INTRODUCTION

Palynology provides the key to stratigraphic correlation within the pre-Tertiary section of the Bight Basin within the Great Australian Bight, southern Australia. This is due to a combination of factors including the lithologies present, specifically the abundance of largely non-calcareous claystone and sandstone in the Jurassic and Cretaceous sections, and the predominant palaeoenvironments within the interval. Palynological data quality is good to excellent, due to both periodic review and updating of the data by researchers and the ongoing re-sampling by the petroleum exploration industry. As a consequence, the tables contained within this chapter provide a firm basis for reliable stratigraphic correlation and seismic mapping. Foraminifera and nanofossils may be useful in parts of the pre-Tertiary sedimentary section, but marginal marine and non-marine sections dominate, and hence yields of those fossil types are typically poor and inconsistent.

In contrast, both microfossils and palynology are applicable for correlation purposes within the Tertiary sediments of the Eucla Basin, overlying the Bight Basin. Foraminifera have proved useful for the Early Eocene to Miocene part of the succession, which is dominated by marine carbonates. However recrystallisation is often a problem, resulting in few specimens being released during processing and difficulty in identifying taxa, even to generic level. Nanofossils have been useful for correlating the marine Middle Eocene to Miocene sediments, but both yield and diversity are generally low and preservation is usually poor. Limited palynological data is available for the Early Paleocene to Late Eocene strata, and possibly into the Oligocene, in Platypus 1.

Throughout this chapter, references to informal zones or subzones are in lower case (for example the upper *F. wonthaggiensis* subzone) and reflect common usage throughout southern Australia, though they have not been formally described. References to wells in relation to the tectonic elements in which they lie reflect a combination of historical usage, and the later naming scheme proposed by Geoscience Australia (this volume, Ch. 4).

MIDDLE JURASSIC TO CRETACEOUS

Palynology

History of zonation

Evolution of the current palynological framework for the Middle Jurassic to Cretaceous has involved many contributors, who are too numerous to reference in this chapter. A more detailed review of the palynological framework for this interval is provided by Morgan et al. (1995). Major cornerstone taxonomic contributions by Isabel Cookson, Alfred Eisenack and Mary Dettmann, and biostratigraphic contributions by Mary Dettmann and Richard Evans, were distilled into the zonation described in Dettmann and Playford (1969). The framework was developed in the Otway, Gippsland and Great Artesian Basins and therefore existed before the first offshore well was drilled in the Bight–Duntroon region. The zonation framework was further refined on a pan-Australian basis by Helby et al. (1987). Morgan (1991) refined the zonation for the former Duntroon Basin — this region comprises areas now called the Duntroon Sub-basin and the eastern Ceduna Sub-basin (Fig. 5.1). A zone name revision was published in Morgan et al. (1995) — *Pilosisporites notensis* for *Cyclosporites hughesii,* to avoid confusion with previous different usage of the *C. hughesii* Zone. Recent taxonomic changes include *Forcipites longus* for *Tricolpites longus, Tubulifloridites lillei* for *Tricolporites lillei* and *Ruffordiaspora* for *Cicatricosisporites.*

The first exploration well, Mallabie 1, which was drilled onshore by Outback Oil Company Ltd on the Madura Shelf, included palynological investigations by Harris et al. (1969). Two main phases of exploration and palynology followed — in the years between 1972–77 and 1990–93. During the first exploration phase, palynologists from Shell Development Australia studied the Echidna 1 and Platypus 1 sections (see Vlierboom 1972a, b respectively), applying in-house Shell units rather than those described by Dettmann and Playford (1969). Both wells were drilled by Shell in the Duntroon Basin in 1972. Shell drilled Potoroo 1 in the far northern Ceduna Sub-basin in 1975 and carried out a detailed palynological investigation which applied the Dettmann and Playford units (Barten, 1975). In 1975 Outback Oil intersected a thin Cretaceous section in both Gemini 1 in the Polda Basin (palynology by Partridge 1976a) and in Apollo 1 (palynology by Partridge 1976b) on the Madura Terrace. Wayne Harris also studied the Apollo 1 stratigraphic section, but the relevant palynology report cannot be located. The Shell wells were reviewed by Von Sanden and Barten (1977), who assigned all to the Playford and Dettmann zones, while providing Shell in-house equivalents (on their figure 3). Shell submitted only one slide from each sample to the government, so the slide sets which are now available are depleted and the missing slides cannot be located.

An additional four wells, mostly shallow tests, were drilled in the period between the two principal phases of exploration activity. In the offshore Polda Basin (Fig. 5.1), Australian Occidental Petroleum drilled Mercury 1 in 1981 (very cursory palynology in Lindsay and Cooper, 1982) and Columbia 1 in 1982 (no palynology) . The drilling of Jerboa 1 (Western Australia) by Esso Exploration and Production Australia Ltd in the Eyre Sub-basin in 1980 provided material for a palynological study by Powis and

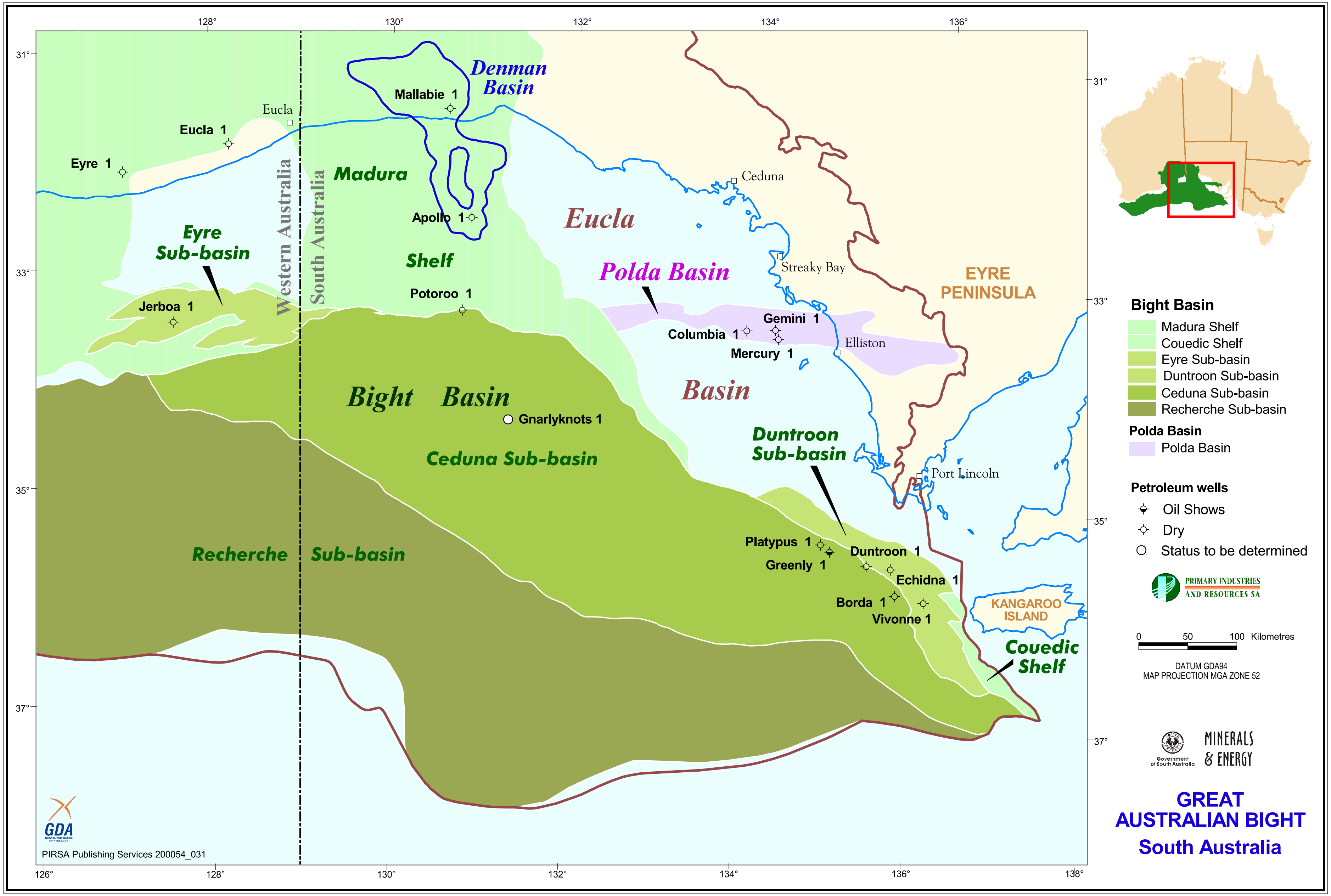


Figure 5.1 Major features and well locations.

Partridge (1980), who used the zones of Helby, Morgan and Partridge (then in preparation and finally published in 1987). Duntroon 1 was drilled in the Duntroon Basin during 1986 by BP Development Australia, with the associated palynological investigation undertaken by Morgan (1986), using the zones of Helby et al. (1987).

In the second phase of exploration activity, the South Australian Mines Department commissioned a rapid re-evaluation of palynological slide sets of the Echidna 1, Platypus 1, Potoroo 1 and Apollo 1 wells, which was published by Morgan (1990). This study highlighted the limitations of the earlier work — especially the patchy sampling, the now incomplete slide sets and the old preparations — and suggested that an extensive new study of the cuttings be carried out to bring these older wells up to the standard seen in Duntroon 1.

BHP Petroleum had already sponsored a detailed re-evaluation of the existing slide sets from the Echidna 1, Platypus 1, Potoroo 1 and Jerboa 1 wells by a PhD student at Monash University (Wagstaff, 1991). Due to apparent differences between Morgan (1990) and Wagstaff (1991), and the recommendations of Morgan (1990), BHP commissioned a significant re-evaluation of Echidna 1, Platypus 1 and Potoroo 1, which involved extensive new sampling of cuttings. This study used the data of Wagstaff on a confidential basis (as it was not open file at the time) and reviewed all of the previous work. The resulting data were distilled into Morgan (1991) who proposed minor revisions to the existing zonation of Helby et al. (1987) to: utilise extinction points, i.e. first downhole occurrence (which is more useful in operational cuttings than inception points (last downhole occurrence)); to substitute more reliable markers to increase resolution; and to generally tailor the pan-Australian zonation for this basin. This zonal scheme and interval assignments were used by BHP as a basis for mapping and subsequent drilling of three exploration wells in the Duntroon Basin during 1993. Greenly 1 was spudded but due to variation to prognosis, urgent palynology was performed onshore, with palynology subsequently transferred offshore to monitor the well to total depth (Morgan and Hooker, 1993a). Greenly 1 was followed by Borda 1 (palynology in Morgan and Hooker 1993b) and Vivonne 1 (palynology in Morgan and Hooker 1993c).

Subsequent work on the palynology of the Bight Basin has been minor, and has been carried out principally to check geochemical data. This new work has included five cuttings samples from Duntroon 1 (Morgan 1995) and five from Jerboa 1 (Morgan 1998). In the Jerboa 1 report, Morgan reviewed previous available data, though the results of Wagstaff (1991) were excluded on the understanding that they were not then open file.

Zonation framework

The zonation used in this chapter and summarised in Figure 5.2 is basically that of Helby et al. (1987), as modified for the Duntroon Basin by Morgan (1991). Minor modifications, where species were unreliable and inconsistent, were made based upon extensive experience regarding the palynology of the southern Australian margin. Other changes were to increase resolution by using additional events to subdivide zones, and to use extinction events to achieve crisp and reliable zonal recognition in cutting samples. Where this was done, an extinction point close to the original definition (usually inception points) was chosen. In addition, unique numerical acmes (or floods) of particular species can be useful correlation horizons, especially when using cuttings. Overall, a change in emphasis to make more use of cuttings-based events has produced a higher resolution in older wells, and enhanced the usefulness of palynology as an operational tool for use during future drilling operations, especially in rig-site situations.

Jurassic

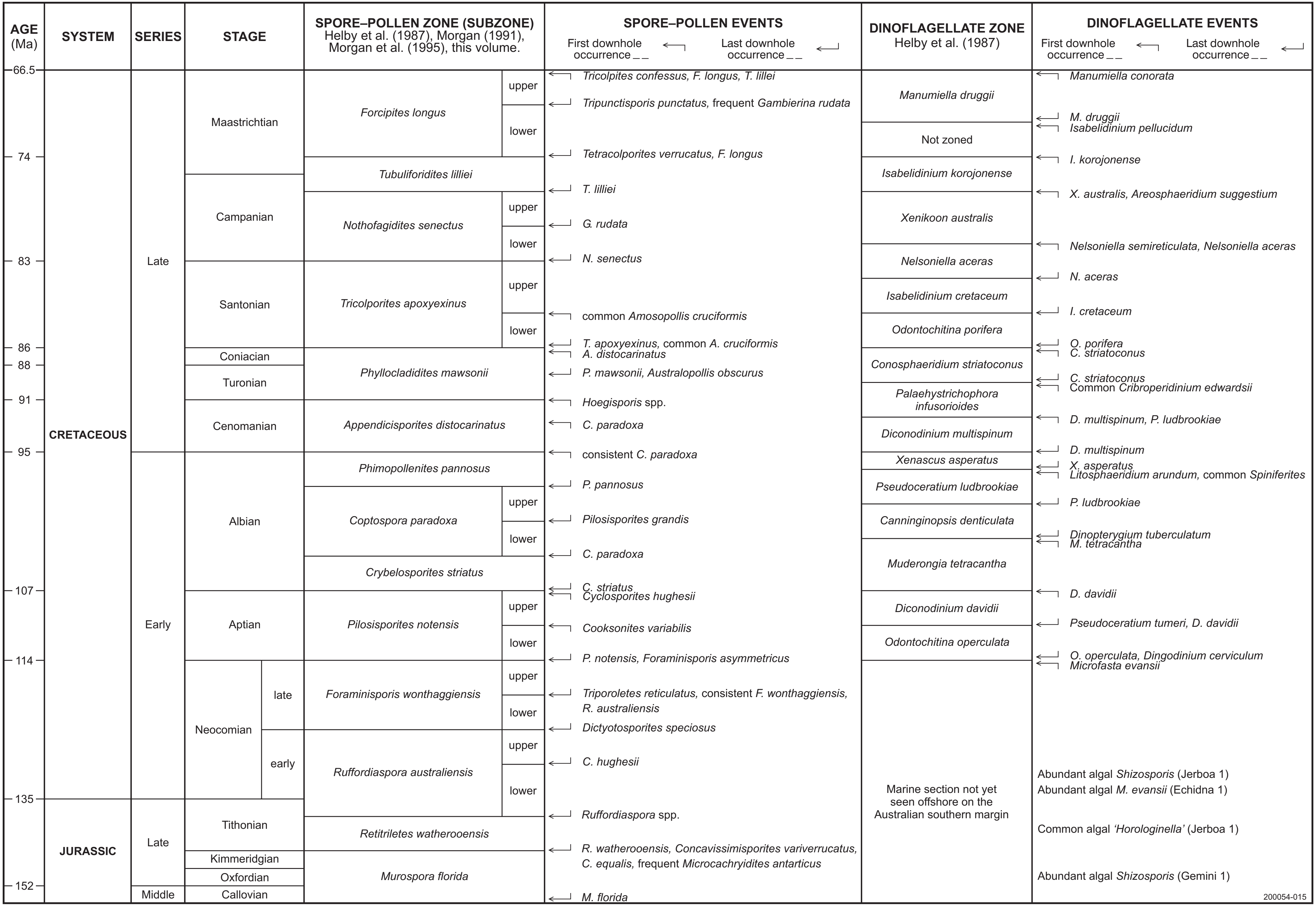
The Middle to Late Jurassic spore–pollen zonal definitions follow Helby et al. (1987).

Early Cretaceous

In the Early Cretaceous there are two exceptions to the Helby et al. (1987) spore–pollen zonal definitions. At the base of the *Foraminisporis wonthaggiensis* Zone, the oldest *Dictyotosporites speciosus* was substituted by Morgan (1991) for oldest *F. wonthaggiensis*, as the latter is scarce and inconsistent at this level in the Bight Basin. At the base of the *P. notensis* Zone, oldest *P. notensis* was substituted for oldest *Foraminisporis asymmetricus*, as the latter is also scarce and inconsistent at this level within the study area. This change might result in the base of the *P. notensis* Zone being picked approximately 50 m higher in some wells.

The change of *F. wonthaggiensis* Zone definition is significant. In Echidna 1 (Duntroon Sub-basin) it results in ~800 m more section being assigned to the zone. Based on one of the author's (Morgan) Australian southern margin experience, the most useful marker between oldest *P. notensis* and oldest *D. speciosus* is oldest *Triporoletes reticulatus,* which usually occurs close to, but above, oldest and inconsistent *F. wonthaggiensis* and oldest consistent *Ruffordiaspora australiensis*. An exception is Vivonne 1, also in the Duntroon Sub-basin, where oldest *F. wonthaggiensis* occurs above oldest *P. notensis,* not below, and highlights the inconsistent occurrence of *F. wonthaggiensis*. Oldest *T. reticulatus* (often close to oldest *F. wonthaggiensis*) defines the base of the upper *F. wonthaggiensis* subzone (Morgan, 1991), as in Figure 5.2, and is approximately equivalent to the *F. wonthaggiensis* Zone, in the strict sense as used by Wagstaff (1991). The lower *F. wonthaggiensis* subzone, upper *R. australiensis* subzone, and lower *R. australiensis* subzone (Fig. 5.2) are all parts of the thick *R. australiensis* Zone in the strict sense as used by Wagstaff (1991).

The use of oldest *D. speciosus* may prove problematic in the western part of the Bight Basin, as it appears to be



AGE (Ma)	SYSTEM	SERIES	STAGE
66.5	CRETACEOUS	Late	Maastrichtian
74			
			Campanian
83			Santonian
86			Coniacian
88			Turonian
91			Cenomanian
95		Early	Albian
107			Aptian
114			Neocomian – late
			Neocomian – early
135	JURASSIC	Late	Tithonian
			Kimmeridgian
			Oxfordian
152		Middle	Callovian

SPORE–POLLEN ZONE (SUBZONE)
Helby et al. (1987), Morgan (1991), Morgan et al. (1995), this volume.

Zone	Subzone
Forcipites longus	upper
	lower
Tubuliforidites lilliei	
Nothofagidites senectus	upper
	lower
Tricolporites apoxyexinus	upper
	lower
Phyllocladidites mawsonii	
Appendicisporites distocarinatus	
Phimopollenites pannosus	
Coptospora paradoxa	upper
	lower
Crybelosporites striatus	
Pilosisporites notensis	upper
	lower
Foraminisporis wonthaggiensis	upper
	lower
Ruffordiaspora australiensis	upper
	lower
Retitriletes watherooensis	
Murospora florida	

SPORE–POLLEN EVENTS

First downhole occurrence ←┐ Last downhole occurrence ←┘

- ←┐ *Tricolpites confessus, F. longus, T. lilliei*
- ←┘ *Tripunctisporis punctatus*, frequent *Gambierina rudata*
- ←┘ *Tetracolporites verrucatus, F. longus*
- ←┘ *T. lilliei*
- ←┘ *G. rudata*
- ←┘ *N. senectus*
- ←┐ common *Amosopollis cruciformis*
- ←┘ *T. apoxyexinus*, common *A. cruciformis*
- ←┐ *A. distocarinatus*
- ←┘ *P. mawsonii, Australopollis obscurus*
- ←┐ *Hoegisporis* spp.
- ←┐ *C. paradoxa*
- ←┐ consistent *C. paradoxa*
- ←┘ *P. pannosus*
- ←┘ *Pilosisporites grandis*
- ←┘ *C. paradoxa*
- ←┘ *C. striatus*
- ←┐ *Cyclosporites hughesii*
- ←┐ *Cooksonites variabilis*
- ←┘ *P. notensis, Foraminisporis asymmetricus*
- ←┘ *Triporoletes reticulatus*, consistent *F. wonthaggiensis, R. australiensis*
- ←┘ *Dictyotosporites speciosus*
- ←┘ *C. hughesii*
- ←┘ *Ruffordiaspora* spp.
- ←┘ *R. watherooensis, Concavissimisporites variverrucatus, C. equalis*, frequent *Microcachryidites antarticus*
- ←┘ *M. florida*

DINOFLAGELLATE ZONE
Helby et al. (1987)

- *Manumiella druggii*
- Not zoned
- *Isabelidinium korojonense*
- *Xenikoon australis*
- *Nelsoniella aceras*
- *Isabelidinium cretaceum*
- *Odontochitina porifera*
- *Conosphaeridium striatoconus*
- *Palaehystrichophora infusorioides*
- *Diconodinium multispinum*
- *Xenascus asperatus*
- *Pseudoceratium ludbrookiae*
- *Canninginopsis denticulata*
- *Muderongia tetracantha*
- *Diconodinium davidii*
- *Odontochitina operculata*
- Marine section not yet seen offshore on the Australian southern margin

DINOFLAGELLATE EVENTS

First downhole occurrence ←┐ Last downhole occurrence ←┘

- ←┐ *Manumiella conorata*
- ←┘ *M. druggii*
- ←┐ *Isabelidinium pellucidum*
- ←┐ *I. korojonense*
- ←┐ *X. australis, Areosphaeridium suggestium*
- ←┐ *Nelsoniella semireticulata, Nelsoniella aceras*
- ←┘ *N. aceras*
- ←┘ *I. cretaceum*
- ←┘ *O. porifera*
- ←┐ *C. striatoconus*
- ←┘ *C. striatoconus*
- ←┐ Common *Cribroperidinium edwardsii*
- ←┐ *D. multispinum, P. ludbrookiae*
- ←┘ *D. multispinum*
- ←┘ *X. asperatus*
- ←┐ *Litosphaeridium arundum*, common *Spiniferites*
- ←┘ *P. ludbrookiae*
- ←┘ *Dinopterygium tuberculatum*
- ←┐ *M. tetracantha*
- ←┐ *D. davidii*
- ←┘ *Pseudoceratium tumeri, D. davidii*
- ←┘ *O. operculata, Dingodinium cerviculum*
- ←┐ *Microfasta evansii*

Abundant algal *Shizosporis* (Jerboa 1)
Abundant algal *M. evansii* (Echidna 1)

Common algal *'Horologinella'* (Jerboa 1)

Abundant algal *Shizosporis* (Gemini 1)

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Figure 5.2 Middle Jurassic to Cretaceous biostratigraphic zonation of the Bight and Polda Basins. (Geochronometric dates correlate to stages and are based on the International Union of Geological Sciences 1989 Global Stratigraphic Chart).

anomalously deep (see below) in Jerboa 1 and is recorded down to the base of *Ruffordiaspora* spp. even further to the west, in the Perth Basin, Western Australia (Backhouse 1988). It may not be as reliable as it currently appears, and further drilling is required to test the matter.

Early Cretaceous dinoflagellate zone definitions follow Helby et al. (1987). However, dinoflagellates are extremely scarce and facies controlled, and continuous dinoflagellate zones cannot be recognised. In some cases dinoflagellate zones can only be identified from caving much deeper in the section (e.g. the *Muderongia tetracantha* Zone in Jerboa 1). Offshore, dinoflagellates have not yet been seen below the Aptian *P. notensis* spore–pollen zone, although onshore data from the Madura Shelf suggest marine equivalents of the upper *F. wonthaggiensis* subzone (see Morgan, 1980, fig. 43; Mallabie 1 below). The presumed freshwater algal form *Microfasta evansii* occurs in the Neocomian, usually in the *F. wonthaggiensis* Zone and older, and a distinctive acme occurs in Echidna 1 with stratigraphic and source rock implications. Overlap between youngest *M. evansii* and oldest *P. notensis* is unusual and generally short, but is significant in Vivonne 1 (see below). If this is real (and not caving of *P. notensis,* reworking or a facies-controlled range extension of *M. evansii*), it may indicate an extra piece of section in the basal lower *P. notensis* subzone seen in Vivonne 1, but lost by unconformity (uplift and erosion?) in Echidna 1. Further drilling in the eastern Bight Basin is required to test this hypothesis.

Late Cretaceous

There is one exception in the Late Cretaceous to the Helby et al. (1987) spore–pollen zonal definitions, the base of the *Phyllocladidites mawsonii* Zone. Youngest *Hoegisporis* spp. is substituted as an extinction event in place of oldest *P. mawsonii,* as *P. mawsonii* is very inconsistent close to its oldest occurrence and cannot be used in cuttings. The effect may be to pick the horizon up to 100 m deeper than on the old criterion, but it will be consistent. Other authors may choose to follow the original definition.

Late Cretaceous dinoflagellate zone definitions follow Helby et al. (1987), with two exceptions. At the top of the *Xenikoon australis* Zone, youngest *X. australis* is substituted for oldest *Isabelidinium korojonense,* as it is a more common species and can be used in cuttings samples. At the top of the *Nelsoniella aceras* Zone, youngest *N. aceras* or *Nelsoniella semireticulata* is substituted for oldest *X. australis,* as it can be used in cuttings and its range in the Duntroon Sub-basin and eastern Ceduna Sub-basin is not as shown by Helby et al. Very rare, low-diversity dinoflagellates occur in many wells, but are inadequate for identification of continuous dinoflagellate zones. The *Conosphaeridium striatoconus* Zone has not yet been seen, but is probably present in more offshore facies.

Wells

Palynology is reviewed on a well-by-well basis below, and summarised in Figure 5.3, in roughly geographic order

SYSTEM	SERIES	STAGE		SPORE–POLLEN ZONE (SUBZONE)		DINO-FLAGELLATE ZONE	BIGHT BASIN																				POLDA BASIN					
							Jerboa 1		Mallabie 1		Apollo 1		Potoroo 1		Echidna 1		Vivonne 1		Platypus 1		Greenly 1		Duntroon 1		Borda 1		Gemini 1		Mercury 1		Columbia 1	
							S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino	S–P	Dino
CRETACEOUS	Late	Maastrichtian		*F. longus*	upper	*M. druggii*							990d		above 1317d	above 1317d			1693s	1693s	2041s	2124s	1839s		2473s	2473s						
																			1798d		2124s		1900d		2671s							
					lower														1850d	?1798d	2211s	2315s	1930d		2723s	2671s						
						Not zoned																										
													1040d						1855s		2550d				2761s							
		Campanian		*T. lilliei*		*I. korojonense*													1881d	1881d	2600d	2600d	1945d		2791s	2791s						
													sandy, no good data						2012s		2745s	2745s	1980d									
				N. senectus	upper	*X. australis*												1359s	2027d	1975d	2825s	2908s	2005d									
																			2118d		3020d		2050d									
					lower												1359s		2163s		3040s	2975s	2085d									
						N. aceras													2164d	2118d	3165s	3280s		2085d								
		Santonian		*T. apoxyexinus*	upper								1332d						2210d	?2301d	3280s	3300d	2124s	2175s								
						I. cretaceum								1322d								3320s		2234s								
													1426d	1426d					2256d		3550s		2201s									
					lower	*O. porifera*							1494d						2301d		3580d		2214s									
													1566d						2438d		3720s		2294s									
		Coniacian		*P. mawsonii*		*C. striatoconus*							1606d						2484d		3776s		2300s									
		Turonian																														
						P. infusorioides		1154s					1758d						2667d	2621d	4255d		2524s									
		Cenomanian		*A. distocarinatus*			1157s	1202s			411s	?411s	1814d						2713d	2896d	4257s		lost by fault									
						D. multispinum		1242s				454s		2018d						2941d												
							1595s	1595s			454s		2430s	2430d					3307d	2987d	4860d											
	Early	Albian		*P. pannosus*		*X. asperatus*	1599s						2446d						3353d				2595s									
						P. ludbrookiae	1631s	1599s				479s	2554s	2446d					3611s				2851s									
				C. paradoxa	upper			1631s			479s		2568s	2610s					3627d				2866s									
						C. denticulata					518s	518s	2634s	2652s					3764d				3020d									
					lower								2652d	2700s					3810d				3056s									
						M. tetracantha		? caved ?		197c		546s	2746d	?2746d					3886d				3141s	3254s								
				C. striatus					192c		?546s			?caved									3181s									
																							3340s	3279s								
		Aptian		*P. notensis*	upper	*D. davidii*			197c	223d					1317d		1372s						3352s									
										259d							1590s						3462s									
					lower	*O. operculata*										1332s	1712s															
									259d						1457s	1420d	2574d															
		Neocomian	late	*F. wonthaggiensis*	upper	Marine section not yet seen offshore on the Australian southern margin	1635d				?560s				1551d		2660s															
							2023s								2013d		3000d															
					lower		2033s						2762s		2042s																no data	no data
							2245s						2794d		2855s																	
			early	*R. australiensis*	upper		2249s								2926d																	
							2265s								3109d																	
					lower		2268s				?614s				3200d																	
							2369s				585s				3831d																	
JURASSIC	Late	Tithonian		*R. watherooensis*			2375s																									
							2490s																									
		Kimmeridgian		*M. florida*																							351d		caved at 1417d			
		Oxfordian																														
	Middle	Callovian																									844d					
PERMO-CARBONIFEROUS									351d		637d																		caved at 1417d			
									Stage 2		Stage 3																					
									427c		863d																					
CAMBRIAN									Cambrian																							
PROTEROZOIC									Neoproterozoic																				Redbeds			
							Crystalline basement		Crystalline basement		Crystalline basement		Crystalline basement														Crystalline basement					

LEGEND

Sidewall core____ 585s

Ditch cuttings____ 351d

Core_________ 197c

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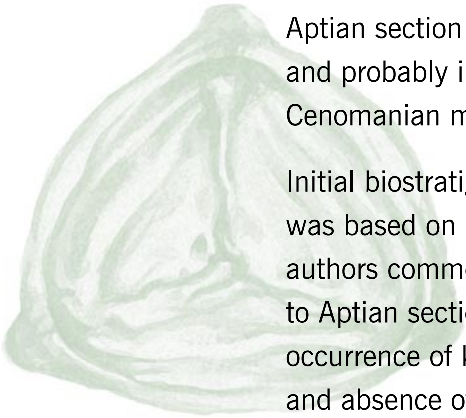
Figure 5.3 Middle Jurassic to Cretaceous biostratigraphy (and older stratigraphy) of wells in the Bight and Polda Basins.

from west to east and onshore to offshore. They have also been grouped by the tectonic element in which they lie. New work, or a re-evaluation of any of these wells, would produce some revision, but are unlikely to produce major changes. The wells are located in Figure 5.1.

Western Bight Basin: Eyre Sub-basin

Jerboa 1

Jerboa 1 is a key well as it represents the only well which has been drilled in the Eyre Sub-basin to date. The pre-Tertiary succession comprises crystalline basement overlain by Late Jurassic to Late Cretaceous sediments. The uppermost Jurassic and Neocomian section are complete and consist of moderately thick, non-marine facies. The Aptian section is missing, and the Albian is marine, thin and probably incomplete. The Late Cretaceous consists of Cenomanian marine sedimentary facies.



Initial biostratigraphic work, by Powis and Partridge (1980), was based on a very extensive sidewall core (swc) suite. The authors commented on problems correlating the Neocomian to Aptian section with eastern Australia due to rare occurrence of key species, delayed occurrence of key species and absence of key species. Some problems still remain, as discussed below. Morgan (1990) assigned the Jerboa 1 section to his zones using the Powis and Partridge (1980) data without discussion, as Jerboa 1 was outside his project brief. He assigned the base of the sediment section to the Cretaceous (not the Jurassic) on the oldest occurrence of the spore–pollen *D. speciosus.* This is discussed and revised below. Wagstaff (1991) produced a new data set from the original slides. Morgan (1998) examined five new cuttings. All data sets were considered in detail for the assignments shown in Figure 5.3 and discussed here. Data sources are Powis and Partridge (1980; identified below as ‘P’), Wagstaff (1991; ‘W’) and Morgan (1998; ‘M’). Sidewall core rock samples exist at Geoscience Australia’s archives and could be restudied.

Thick Late Jurassic to Neocomian section occurs in non-marine facies, but zonal assignment is not straightforward, and the data could be interpreted in a number of different ways. Ambiguities are caused partly for the reasons outlined by Powis and Partridge (1980), but also by differences in the two data sets. Anomalously deep, single records of key species may be caused by mud contamination, or may be real, and represent different ranges in Western Australia.

The *R. watherooensis* Zone markers include oldest *R. watherooensis* (2420 m, P; 2456 m, W), *C. equalis* (2420 m, P; 2490 m, W), *M. antarcticus* (2420 m, P; 2490 m, W) and *C. variverrucatus* (2427 m, P; 2448 m, W). *Callialasporites dampieri* is mostly rare (1–2%) and reaches a maximum of 7% (2440 m, W). All this section is assigned to the *R. watherooensis* Zone herein, on the basis of the Wagstaff data, and in contrast to previous workers. Alan Partridge (Latrobe University, pers. comm., 1999) agrees. Cuttings at 2400–2405 m contain 17% algae

(Morgan, 1998), including some bizarre *'Horologinella'* types (Plate 5.1), and the freshwater dinoflagellate *Tetrachacysta baculata* of Backhouse (1988) from the Perth Basin. These algae may have good oil-source potential.

The lower *R. australiensis* subzone base marker (oldest *Ruffordiaspora* spp.) is very inconsistent. All samples are swcs. Wagstaff records *Ruffordiaspora* spp. consistently down to 2043 m, then at 2083, 2088 and 2340 m. Powis and Partridge record them consistently to 2043 m, then 2118, 2340, 2353 and 2369 m. Herein, 2369 m is taken as the absolute base, but scarcity means that this is only approximate. Oldest *M. evansii* occurs at 2295 m (P and W), and supports the assignment. Cuttings at 2350–2355 m contain 13% algae (Morgan, 1998) and may represent good oil-source rocks.

The upper *R. australiensis* subzone base marker (oldest *C. hughesii*) is problematic, being very inconsistent in the Wagstaff data, with deep records at 2083, 2182, 2265, ?2273 and 2382 m (all swcs). The Powis and Partridge data record *C. hughesii* fairly consistently (in swcs) down to 2108 m, inconsistently to 2245 m, then at 2340 m. Herein, 2265 m (W) is taken as the most likely base, with the deeper records (2340 m, P; 2382 m, W) close to oldest *Ruffordiaspora* spp. considered probable mud contamination.

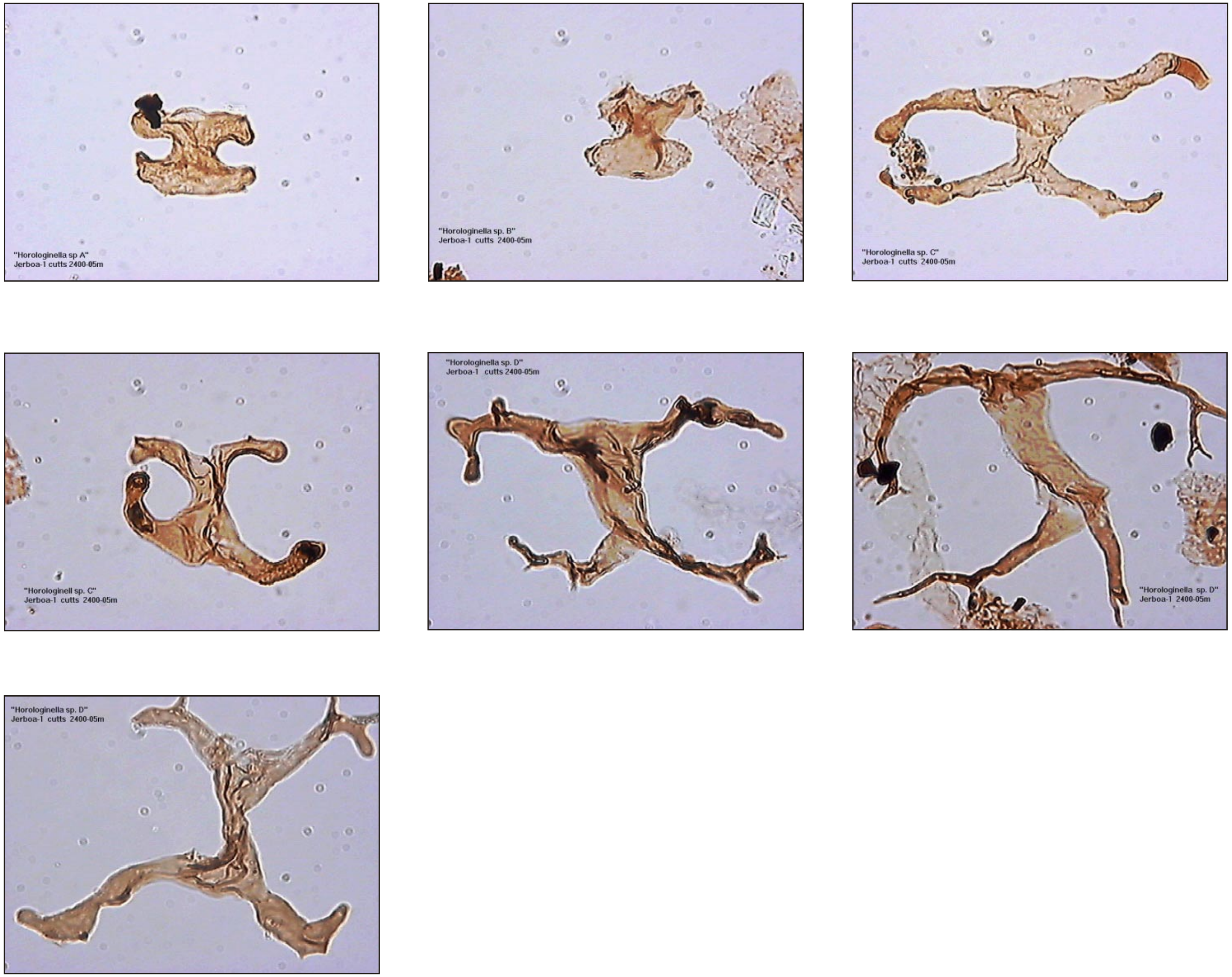
The lower *F. wonthaggiensis* subzone base marker (oldest *D. speciosus*) is highly problematic, being very consistent (to 1494 m, P; 2108 m, W), inconsistent (to 2245 m, P; 2245 m, W) and very inconsistent below 2245 m (at 2332, 2340, 2369 and 2448 m only in Powis and Partridge (1980)). All samples are swcs. Herein, 2245 m is taken as the 'best consensus' oldest occurrence. The deeper Powis and Partridge (1980) occurrences, together with whether 2245 m represents a real downward range extension compared with the wells from the Duntroon Sub-basin in the far eastern part of the basin, are open to interpretation. This zonal assignment represents a significant change from Morgan (1990).

The upper *F. wonthaggiensis* subzone is straightforward, defined at the base by oldest consistent *T. reticulatus* (2018 m, P; 2023 m, W) and supported by oldest *F. wonthaggiensis* (1933 m, P; 2018 m, W) and consistent *R. australiensis* (2043 m, P, W). The top is defined by the youngest *M. evansii* (1635 m, P, W) and the absence of younger markers, especially *P. notensis.*

Phimopollenites pannosus Zone is identified on youngest consistent *C. paradoxa* at the top (1599 m, W) and oldest *P.* cf. *pannosus* at the base (1631 m, W). *Appendicisporites distocarinatus* Zone is identified on youngest *A. distocarinatus* (1157 m P, W) and *Hoegisporis uniforma* (1167 m, W) at the top, and the absence of older markers at the base.

Dinoflagellate zones occur in this interval. The *M. tetracantha* Zone may be present, as *M. tetracantha* was

Plate 5.1 *Horologinella sp*. **A, B, C and D, Jerboa 1 cuttings, 2400–05 m.**



seen in cuttings at 2100–2105 m by Morgan (1998). It is presumably condensed in the sample gap 1631–1635 m (swc). The *Pseudoceratium ludbrookiae* Zone is identified on youngest *Litosphaeridium arundum* (1599 m, P), *Dinopterygium tuberculatum* (1611 m, P) and *Dioxya armata* (1615 m, P) at the top without *Xenaseus asperatus*, and oldest *P. ludbrookiae* (1631 m, P; 1623 m, W) at the base. The *Diconodinium multispinum* Zone is identified on youngest *P. ludbrookiae* (1242 m, P, W) and youngest consistent *D. multispinum* (as *Diconodinium dispersum* at 1242 m, P) at the top, and absence of older markers at the base. The *Pseudoceratium infusorioides* Zone is identified on youngest *Cribroperidinium edwardsii* (1154 m, P; 1157 m, W; with a single *D. multispinum* (as *D. dispersum* — considered reworked)) and the absence of older markers at the base.

North–central Bight Basin: Madura Shelf

Only two of the Madura Shelf wells have been investigated in this study, namely Mallabie 1, located near the coast, and Apollo 1, located ~150 km to the south in the offshore.

Mallabie 1

The pre-Tertiary succession in Mallabie 1 comprises crystalline basement which is overlain by sediments of Proterozoic and Cambrian age (Von Sanden and Barten 1977), Permo-Carboniferous and finally Early Cretaceous. The Cretaceous sequence consists of thin, Aptian to early Albian, marine sediments.

Harris et al. (1969) studied the palynology of cores and cuttings. These preparations were briefly scanned for this study and are discussed below. Existing preparations are lean and poor, and new processing would increase the confidence of the interpretation.

Latest Carboniferous to Early Permian Stage 2 microfloras are described from core and cuttings in glacigene rocks in the interval 351–427 m (Harris et al., 1969), and therefore are apparently slightly older than those in Apollo 1.

No detailed Cretaceous range data is given by Harris et al. (1969). However, the species list includes the dinoflagellate *Dingodinium cerviculum* and the spores *C. hughesii* and *F. wonthaggiensis* from core and cuttings, which suggests a Neocomian age. Re-examination of the existing slide set indicates the Aptian *Diconodinium davidii* dinoflagellate zone in cuttings (*D. davidii* and *D. cerviculum* at 222.5–259.1 m, with *D. davidii* abundant at 253.0–259.1 m) and the early Albian *M. tetracantha* dinoflagellate zone at 196.9 m (*M. tetracantha* without older markers). Spore–pollen zones include the *P. notensis* Zone (on *F. asymmetricus* to the base without younger markers) and the *Crybelosporites striatus* Zone (on *C. striatus* without younger markers) at 192.0 m (core). These zones and several key species were not described by Harris et al. (1969). Marine section of the same age occurs nearby onshore (Morgan, 1980, fig. 43).

Apollo 1

The pre-Tertiary succession in Apollo 1 comprises crystalline basement overlain by Denman Basin Permian and Cretaceous sediments. The Early Cretaceous consists of thin, very lean, non-marine Neocomian section and thin, marine Albian section. The Late Cretaceous consists of Cenomanian marine sedimentary facies.

Sidewall cores were prepared for study by Wayne Harris in 1975, but no report relating to this can be located and the work is mentioned in only a few lines in a memo to Outback Oil. Partridge (1976b) studied preparations from cuttings but did not give detailed occurrence data. He briefly scanned Harris's swc preparations and gave key species listings. Morgan (1990) rapidly scanned the same preparations and plotted key events against logs. The breakdown in Figure 5.3 follows Morgan (1990), with minor modification in the upper *Coptospora paradoxa* spore–pollen subzone using the Partridge data. A re-examination of swcs may clarify the Permo-Carboniferous and Neocomian, but would probably not alter the breakdown significantly.

The Permian is assigned to Stage 3, based on Partridge's cuttings data, but a partly slightly older Stage 2 assignment is not impossible if key elements are caved. The swc at 614 m is barren, but a Cretaceous age seems more likely than Permian. The Neocomian is lean and a zonal assignment is not possible, but *Perotriletes linearis* and *Crybelosporites stylosus* at 585 m (swc) indicate a broad Neocomian age. The Albian and Cenomanian section are well controlled by dinoflagellates and by spores and pollen.

CENTRAL BIGHT BASIN: CENTRAL CEDUNA SUB-BASIN

Potoroo 1

Potoroo 1 is located at the extreme northern edge of the Ceduna Sub-basin, on the border with the Madura Shelf. The pre-Tertiary succession comprises crystalline basement overlain by Cretaceous sediments. The Early Cretaceous is thin and incomplete, and comprises a thin, non-marine, late Neocomian non-marine section, and absent uppermost Neocomian to early Aptian section, and a middle to late Albian marine facies. The Late Cretaceous is marine to marginally marine and sandy, especially towards the top. The Cenomanian is especially thick, but the Campanian and most of the Maastrichtian cannot be identified, although it is possibly present.

The original palynological data were generated by Barten (1975) and reviewed by Von Sanden and Barten (1977). The depleted slide set was scanned briefly by Morgan (1990), who recommended a new study of the cuttings. Wagstaff (1991) studied the slide set in detail. Morgan (1991) examined new cuttings, reviewed all the earlier work, plotted key events from all sources against logs, and produced the breakdown shown in Figure 5.3, with two exceptions. The base of the lower *F. wonthaggiensis* subzone is revised upward to 2794 m (cuttings), as it is clearly caved into crystalline basement at 2822 m. Possible dinoflagellate fragments of *M. tetracantha* at 2746 m (cuttings) also suggest the presence of the *M. tetracantha* Zone nearby.

Polda Basin

Three wells, Gemini 1, Mercury 1 and Columbia 1, have been drilled in the offshore part of the Polda Basin, which is an E–W trending feature located in the eastern part of the Great Australian Bight basins, ~250 km north-northwest of the Duntroon Sub-basin (Fig. 5.1).

Gemini 1

The pre-Tertiary section in Gemini 1 comprises ?crystalline basement / ?Jurassic basalts overlain by Late Jurassic sediments. Partridge (1976a) studied cuttings and noted the similarity to the onshore part of the Polda Basin. Sidewall core preparations were made by Harris in 1975, but no report resulting from this work can be located. The samples exist and could be restudied. Spore–pollen are assigned here to the *Murospora florida* Zone because they contain *M. florida* without younger markers (such as *Ceratosporites equalis, Concavissimisporites variverrucatus* and frequent *Microcachryidites antarcticus*). *Retitriletes watherooensis* was not recorded, but it was not described or named until 1978. Partridge (1976a) also noted abundant algal *Schizosporis* (as *Spheripollenites*) at 387–396 m (cuttings) and this may indicate that the interval has some source rock potential.

Mercury 1

Mercury 1's pre-Tertiary succession comprises ?Neoproterozoic redbeds, overlain by Permo-Carboniferous and Late Jurassic sediments. The only palynological data available are from Lindsay and Cooper (1982), who studied claystone chips caved into a redbed sequence in the interval 1417–1442 m. Caved pre-Tertiary elements include presumed Permo-Carboniferous and Late Jurassic elements. Wayne Harris is quoted as confirming the presence of both in the well, presumably on lithological criteria.

Columbia 1

No palynological data are available for Columbia 1. The section is similar to the nearby Polda Basin wells and lithological correlations may have been considered sufficient.

Eastern Bight Basin: Duntroon and eastern Ceduna Sub-basins

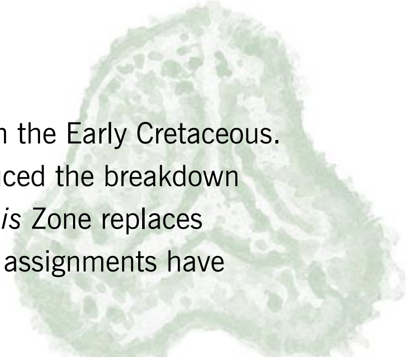
A total of six wells have been drilled in the eastern part of the Bight Basin, the shallow water part of which is termed the Duntroon Sub-basin, with the deeper water component being part of the Ceduna Sub-basin. These wells are Echidna 1 and Vivonne 1 in the Duntroon Sub-basin and Platypus 1, Greenly 1, Duntroon 1, and Borda 1 in the eastern Ceduna Sub-basin. As such, the eastern Bight Basin is by far the most intensively drilled and provides the best opportunity for detailed biostratigraphic correlation.

Duntroon Sub-basin

Echidna 1

Echidna 1 reached total depth within the Early Cretaceous, lower *R. australiensis* subzone. The Early Cretaceous in Echidna 1 is incomplete. A thick and complete Neocomian section is overlain by a thin, Aptian, marginal marine section and all of the Albian is missing. At the base (3658–3831 m), the algal *M. evansii* is abundant, suggesting deposition with a lacustrine environment and the possible presence of oil-prone source rocks. The only evidence of Late Cretaceous sediments is a Maastrichtian *F. longus* spore–pollen zone caving within the Aptian cuttings sample at 1317 m. They must occur above this point, probably as a thin sliver of sediment.

The original swc-based data set of Vlierboom (1972a) was reviewed by Von Sanden and Barten (1977). Morgan (1990) briefly scanned the depleted slide set and proposed a new study of the cuttings. Wagstaff (1991) restudied the slide set. Morgan (1991) studied new cuttings, reviewed all the previous data and plotted key events from all sources against logs, producing the breakdown shown in Figure 5.3 with two exceptions. The *P. notensis* Zone replaces *C. hughesii* as a name change. The base upper *F. wonthaggiensis* subzone has been moved slightly (to 2013 m from 2042 m) to coincide with oldest *T. reticulatus*, now considered the most reliable of the available markers.



Vivonne 1

Vivonne 1 reached its total depth in the Early Cretaceous. Morgan and Hooker (1993c) produced the breakdown shown in Figure 5.3. The *P. notensis* Zone replaces *C. hughesii* as a name change. No assignments have changed.

The Early Cretaceous comprises a late Neocomian section, probably non-marine, and a thick Aptian section, with extremely rare dinoflagellates. Dinoflagellates occur as rare components in swcs at 1473.0, 1590.0 and 1712.0 m and only in cuttings beneath, where their presence may entirely be the result of caving. At the base, 340 m is assigned to the upper *F. wonthaggiensis* subzone, based on youngest algal *M. evansii* up to 2660.0 m (swc) and is considered late Neocomian. However, the spore–pollen *P. notensis* does occur in swcs down to 2660.0 and 2796.4 m and occurs in cuttings to the base (3000 m), and suggests that at least part of the interval belongs to the Aptian *P. notensis* Zone. Overlap of these two species has not been seen elsewhere in the basin and may be false, resulting from reworking of *M. evansii,* or caving and mud contamination of *P. notensis.* If the overlap is real, it may represent section seen here but lost from Echidna 1 in the sample gap from 1457–1551 m. More wells must be drilled to resolve this uncertainty, assuming no more swcs are available for study.

The Late Cretaceous is sandy, condensed and incomplete and controlled by a single, marine swc. New cuttings located on the gamma spikes might provide more control, but lithologies are unfavourable.

EASTERN CEDUNA SUB-BASIN

Platypus 1

Platypus 1 reached total depth in Early Cretaceous, middle to late Albian, thick non-marine sediments. The Late Cretaceous sequence is complete and consists of near-shore, to marginally marine, to non-marine facies. Sediments are sandy only in the late Campanian to Maastrichtian, but sufficient claystones exist to get good control. The Cenomanian is particularly thick, with marine influence seen only in the upper part of the section (above 2958 m swc, or 2987 m cuttings).

The original swc-based data set was generated by Vlierboom (1972b) and reviewed by Von Sanden and Barten (1977). The depleted slide set was briefly scanned by Morgan (1990), who recommended a new study of the cuttings. Wagstaff (1991) examined the slide set in detail. Morgan (1991) studied extensive new cuttings, reviewed the previous work, plotted key events from all sources against logs, and produced the breakdown shown in Figure 5.3, with two exceptions. The dinoflagellate *P. infusorioides* Zone is recognised herein on top common *C. edwardsii*, as shown in Morgan (1991), and the lower and upper *N. senectus* spore–pollen subzones are identified. The base of the *P. pannosus* Zone (3611 m swc herein) may be as low as 3659 m (swc), as Vlierboom (1972b) logs an isolated *P. pannosus* there, or as low as 3863 m (swc) as Alan Partridge (Latrobe University, pers. comm., 1999) has logged it there. Morgan's (1991) choice, retained here, is unlikely to be far wrong given that youngest *P. notensis* is logged at 3863 m (swc) by Vlierboom (1972b), and is inferred at 3746 m by Von Sanden and Barten (1977).

Greenly 1

Greenly 1 reached total depth within Late Cretaceous sediments. The well penetrated a very thick and complete Late Cretaceous section, especially in the Cenomanian to Santonian *A. distocarinatus* to *Tricolporites apoxyexinus* spore–pollen zones. Sedimentary facies are mostly very near-shore marine.

The data of Morgan and Hooker (1993a) are particularly good, being based on over 100 samples, including 40 swcs and extensive cuttings, mostly processed and examined offshore at rigsite. The breakdown in Figure 5.3 is unaltered from the original report in which key events are plotted against logs.

Sediments at total depth, in the *A. distocarinatus* Zone, may be non-marine: dinoflagellates are absent from swcs below 4798.0 m and their occurrence in cuttings below this depth may be entirely caved. Dinoflagellate zones cannot be identified below the Santonian *Isabelidinium cretaceum* Zone at 3320 m; dinoflagellates below that point are mostly minor, at least partly caved, and lack zone diagnostic species. Notably, the Cenomanian *D. multispinum* Zone cannot be recognised in Greenly 1, in contrast to Potoroo 1 and Platypus 1, presumably due to the less marine facies.

Duntroon 1

Duntroon 1 reached total depth within an Early Cretaceous sedimentary sequence. These sediments range from mid-Aptian (*P. notensis* Zone) to complete Albian and are mostly non-marine to brackish facies. Near-shore marine environments occur as a thin, early Albian interval (*M. tetracantha* Zone). The Late Cretaceous section is complete in marine to marginally marine facies, except at the base where the *A. distocarinatus* Zone is missing. It is assumed to have been removed by faulting.

The report of Morgan (1986) was modified slightly by Morgan (1991) to produce the breakdown shown in Figure 5.3. One spore–pollen zone name has been changed herein to update the data (*P. notensis* for *F. asymmetricus*), and the upper and lower *N. senectus* subzones are recognised. Key events are shown against logs in the review by Morgan (1991), who identified extra events of use, using the Morgan (1986) raw data set to achieve higher resolution correlation to Platypus 1 and Potoroo 1. The cuttings data of Morgan (1995) does not alter the breakdown, and was directed to assess the validity of geochemistry.

Borda 1

Borda 1 was a basal Tertiary to top Cretaceous test, so it penetrated only the uppermost part of the Late Cretaceous. The well was completed in the Campanian *T. lillei* Zone. The topmost Campanian and Maastrichtian section were intersected and consist of very sandy near-shore and very near-shore facies. The breakdown shown in Figure 5.3 is unaltered from Morgan and Hooker (1993b). Key events were plotted against logs in that report. Close-spaced swcs and two cuttings were studied as 'hot shots' to confirm the age at total depth.

Foraminifera

The only attempt to correlate Cretaceous foraminifera from the Bight Basin with a zonal scheme has been by Apthorpe (1972a). In her examination of Platypus 1 she identified two of David Taylor's zonules (XA and XC) and tentatively identified a third (XB; see Apthorpe, 1972a, encl. 8).

Most of the foraminifera are benthonic. These are mainly arenaceous, notably *Haplophragmoides audax*, which indicates a late Aptian to late Albian, or younger, age (e.g. Scheibnerova, 1980). Arenaceous forms are indicative of a restricted marine environment of deposition and have been recorded from: the Madura Formation and equivalent within Apollo 1 (Madura Shelf; Taylor, 1975a) and Jerboa 1 (Eyre Sub-basin; Conley, 1980), the Platypus Formation (corresponding to the White Pointer sequence) in Potoroo 1 (northern Ceduna Sub-basin; Taylor, 1975b); and the Potoroo and Wigunda Formations (corresponding approximately to the Hammerhead and Tiger sequences respectively) in Platypus 1 (eastern Ceduna Sub-basin; Apthorpe, 1972a). Calcareous benthonic species, which are indicative of more normal marine conditions, are rare, and have been recorded only from the Madura Formation in Apollo 1 (*Saracenaria kattarensis;* Taylor, 1975a) and the Potoroo and Wigunda Formations in Platypus 1 (Apthorpe, 1972a).

The only planktonic species recorded (*Hedbergella delrioensis*; Conley, 1980) is from sediments in Jerboa 1, which were assigned by Huebner (1980) to Madura Formation equivalent. This species ranges from Aptian to Maastrichtian.

Summary

Existing drilling has been in shallower water for logistical reasons and hence incomplete, eroded or non-deposited sections are the norm, rather than the exception . The area is very sparsely drilled, especially in the west — such as in the western Ceduna and the Eyre Sub-basins, while the deep-water Recherche Sub-basin remains undrilled. Future drilling, particularly in deeper water, may provide more complete, and also more marine sections, especially in the Neocomian, Jurassic and older intervals. The availability of these sections will provide the opportunity to test the existing zonations and search for marine equivalents of the nearer shore facies tested by the wells currently available in the shallow water. In addition, deep water drilling may help to locate potentially prolific, oil-prone, marine and algal lacustrine source rocks in the developing southern rift and also to understand palynological relationships between the Bight Basin and the well studied Perth Basin and the Naturaliste Plateau further to the west.

Permian to Middle Jurassic

Permian section has been intersected in the Mallabie 1, Mercury 1 and Apollo 1 wells, where it overlies metasedimentary or crystalline basement. Triassic sedimentary section has not been drilled to date, but reworked Triassic palynomorphs occur regularly and hence Triassic section probably exists in deeper parts of the basin, or as small, perhaps isolated, remnants. Early Jurassic section has not yet been drilled either. Middle to Late Jurassic section has been identified offshore in the Eyre Sub-basin to the west (Jerboa 1) and within the Polda Basin in the east (intersected in Gemini 1, Mercury 1 and Columbia 1 and onshore). This section is uniformly non-marine and contains significant, algal-rich intervals. Large, algal-rich, lake systems may be much more extensive at depth in the deep rift system, in deep water offshore from the area of present well control, and may provide a rich, and critically, oil-prone source interval.

Cretaceous

The Early Cretaceous Neocomian sequence is widespread and directly overlies crystalline basement in Potoroo 1, located in the far northern Ceduna Sub-basin. In many other wells the Cretaceous has not been fully penetrated. Algal-rich intervals occur near the base (in the lower *R. australiensis* subzone) at least in both Jerboa 1 (Eyre

Sub-basin) and Echidna 1 (Duntroon Sub-basin) and may be areally extensive within the basin, particularly within the more central parts of the Cretaceous rift in deeper water. The Neocomian section which has been intersected to date is non-marine. It is very thick in Echidna 1 (in the east, in the Duntroon Sub-basin), moderately thick in Jerboa 1 (to the west, in the Eyre Sub-basin), but thin and incomplete in the central parts of the Bight Basin at Potoroo 1 (far northern Ceduna Sub-basin) and Apollo 1 (Madura Shelf). It has been only partly penetrated in Vivonne 1, within the Duntroon Sub-basin, in the east. Marine equivalents of the late Neocomian upper *F. wonthaggiensis* subzone probably exist onshore in the Eucla Basin in Western Australia (Morgan, 1980).

Aptian section is best developed in non-marine facies in Vivonne 1, but thin, incomplete sections also occur in two other wells in the eastern Bight Basin — Duntroon 1 (non-marine) and Echidna 1 (marginally marine). A thin and incomplete marine Aptian sequence is also present in Mallabie 1 on the Madura Shelf. Marine influence probably becomes much more significant towards the centre of the rift, in what is now deep water. Albian section is more widespread and shows weak and ephemeral marine influence at different levels in several locations — Potoroo 1, Apollo 1 and Jerboa 1, in the central and western Bight Basin, are the most marine, with a thin marine section present in the Mallabie 1 well. In the eastern Bight Basin the equivalent lower section is largely non-marine in Duntroon 1 and is entirely non-marine in Platypus 1. This may indicate a general trend from a more marine Albian section in the western and central Bight Basin, to a less marine or non-marine sequence in the Duntroon and Ceduna Sub-basins in the east. Marine Aptian and Albian occur elsewhere onshore, such as in the platformal areas underneath the Eucla Basin, and they are also extensive in the Officer and Great Artesian Basins to the north. Rare and ephemeral marine influence of this age also occurs in the Otway Basin, immediately to the east of the Bight Basin.

Cenomanian deposition was also rapid and widespread in the Apollo 1, Jerboa 1, Potoroo 1, Platypus 1 and Greenly 1 wells, but appears to have been faulted out at the Duntroon 1 well location. Marine influence occurs to the base of the Cenomanian in Jerboa 1, Apollo 1 and Potoroo 1 (central and western Bight Basin), but becomes established only later in the Cenomanian, further to the east in the eastern Ceduna Sub-basin (Platypus 1, Greenly 1).

The rest of the Cretaceous (Turonian to Maastrichtian) was deposited more slowly in near-shore to marginally marine environments, but the restricted marine facies prevents recognition of all zones in all wells. The sequences are fairly complete in Potoroo 1, Platypus 1, Greenly 1 and Duntroon 1, but are very incomplete in Echidna 1 and Vivonne 1 (Duntroon Sub-basin), with only the top intersected in Borda 1 (eastern Ceduna Sub-basin). The section also becomes more sandy towards the top of the time interval, and progressively more sandy from Greenly 1 through to Duntroon 1, Platypus 1 and Potoroo 1. Very sandy lithologies at the top of the sequence in Potoroo 1 prevent recognition of all the zones, though the section may actually be complete.

TERTIARY

Palynology

Zonation

Morgan et al.'s (1995) detailed discussion of the Tertiary palynology framework (Otway Basin) noted that the existing zonation had limited application outside of SE Australia, and that modifications were necessary if this scheme was to have a regional application. Recent work by Macphail et al. (1994) incorporates palynological data from other regions of Australia (central and NE Australia, and Western Australia) into the existing Stover and Partridge (1973, 1982) zonation.

The Tertiary dinoflagellate zonation remains of little use, with all existing schemes based on undefined zones and requiring considerable refinement (i.e. Partridge, 1976c; Harris, 1985; Morgan and Hooker, 1993a). This is unfortunate because dinoflagellates are more abundant than spore and pollen in the Tertiary sediments recovered from the Bight Basin.

Wells

Palynology is reviewed below on the same well-by-well basis used for the Cretaceous. Paucity of existing Tertiary spore–pollen data and deficiencies in the existing dinoflagellate schemes have made any age revisions difficult. Only an expanded summary of the original age determination has been possible. Ages based solely on dinoflagellate zones must be treated with caution. Most workers have tried to correlate with the existing spore–pollen zonation.

Western Bight Basin: Eyre Sub-basin

Jerboa 1

Palynomorph yields over the Tertiary interval from 1120.5–1075.0 m in Jerboa 1 are generally low, and, in the absence of diagnostic spore–pollen indicators, dinoflagellate assemblages (including several undescribed species) have been used in dating by Powis and Partridge (1980). Yields are extremely low in the younger sediments.

At 1106 m *'Hologinella'* sp. aff. *H. spinosa* is suggested by Powis and Partridge (1980) as being associated with the Middle Eocene *Wilsonidium echinosuturatum* dinoflagellate zone and correlates with the early Lower *Nothofagidites asperus* spore–pollen zone.

At 1096 m, a Middle Eocene age is assigned on the presence of *Areosphaeridium dictyoplokus* (i.e. *Areosphaeridium dictyoplokum* of Williams et al., 1998), *Impagidinium maculatum, Rhombodinium glabrum, and*

Senoniasphaera compta m.s. *R. glabrum* is recognised as a rare species of the Middle Eocene *Achilleodinium biformoides* Zone (Harris, 1985) and the *Areosphaeridium australicum* Zone (of Partridge (unpublished) as used by Morgan and Hooker, 1993c), both of which correlate to the Lower *N. asperus* Zone.

At 1075 m, the presence of *Corrudinium corrugatum* m.s. and *Tectatodinium marlum* m.s. indicate an age no younger than Late Eocene.

CENTRAL BIGHT BASIN: CENTRAL CEDUNA SUB-BASIN

Potoroo 1

In Potoroo 1 Barten (1975) recorded Tertiary sediments at 945–967 m of Late Paleocene to Early Eocene age, which had both rich palynomorph and microplankton assemblages. The basal Tertiary assemblage (967 m) is assigned to the *Lygistepollenites balmei* spore–pollen zone on the occurrence of the dinoflagellates *Cyclonephelium vitilare, Deflandrea metcalfii, Deflandrea pentaradiata* and *Wetzeliella articulata* (Barten, 1975).

Re-interpretation of Barten's palynological data has resulted, herein, in a slightly younger age for assemblages from 945 to 950 m. Assignment to the *Proteacidites asperopolus* spore–pollen zone is based on the common occurrence of *Haloragacidites harrisii*, *Nothofagidites* spp. and *Proteacidites pachypolus,* in association with *Proteacidites crassus, Proteacidites latrobensis* (i.e. *Proteacidites crassipora* of Barten, 1975) and *Myrtaceidites tenuis.*

The occurrence of the dinoflagellates *Homotryblium tasmaniense* and *Diphyes colligerum*, in association with *Deflandrea phosphoritica* and *Wetzellia glabra*, supports an Early to Middle Eocene age and could be assigned to Harris's *H. tasmaniense* Zone (which correlates with the *P. asperopolus* spore–pollen zone). A similar spore–pollen assemblage at 952 m would warrant its inclusion in the *P. asperopolus* Zone.

EASTERN BIGHT BASIN: DUNTROON AND EASTERN CEDUNA SUB-BASINS

DUNTROON SUB-BASIN

Vivonne 1

Morgan (1993) identified the Tertiary interval (975.0–1219.0 m) in Vivonne 1 as undifferentiated Tertiary at the base, through Middle to Late Eocene. Dinoflagellate assemblages dominate the interval above 1128.0 m, with spores and pollen generally rare. Morgan (1993) recognised three dinoflagellate and two spore–pollen zones: the lower Middle Eocene *A. australicum* dinoflagellate zone (= Lower *N. asperus* spore–pollen zone) at 1050.0 m, the Middle Eocene *D. heterophlycta* Zone (= uppermost Lower *N. asperus* Zone) at 1010.0 m and the Late Eocene *C. incompositum* Zone (= Middle *N. asperus* Zone) at 975.0 m.

Assignment to the *A. australicum* Zone is indicated by the rare occurrence of the dinoflagellate *R. glabrum* and common *A. arcuatum* in the absence of younger markers.

Assignment to the *D. heterophlycta* Zone is based on the common occurrence of *D. heterophlycta.* The spore–pollen assemblage is represented by rare *L. florinii.*

The *C. incompositum* Zone is identified on the presence of *C. incompositum* and *T. spinosus* in an assemblage dominated by *Spiniferites ramosus* with abundant *D. phosphoritica* and *Operculodinium* spp. and rare *Thalassiphora pelagica*. In the spore–pollen assemblage the presence of *Nothofagidites falcatus* would support assignment to the Middle *N. asperus* Zone.

Echidna 1

The Tertiary interval in Echidna 1 is represented by a single ditch cutting sample (1255.8 m). Palynological data is lacking in quantitative details, but it is evident from the species list provided that while a diverse dinoflagellate assemblage exists, spores or pollen are rare. Vlierboom (1972a), in commenting of the ranges of *D. colligerum, D. phosphoritica, Baltisphaeridium* cf. *transtodum* and *Microdinium* cf. *irregulare*, assigned a Lower Eocene age. Harris (1985) recognised *D. colligerum* as an associated species of the *H. tasmaniense* dinoflagellate zone, which correlates with the Early to Middle Eocene *P. asperopolus* spore–pollen zone.

EASTERN CEDUNA SUB-BASIN

Platypus 1

In Platypus 1 Vlierbloom (1972b) recorded probable Eocene sediments over the interval 1645.9–1676.4 m on the basis of long ranging non-descript taxa, and Early Eocene sediments over the interval 1691.6–1842.8 m. The Early Eocene assignment is supported by his records of *P. pachypolus, M. diversus, C. orthoteichus* and *I. notabilis* which suggest assignment to the upper *M. diversus* Zone of Partridge and the equivalent *C. orthoteichus* Zone of Harris. However, Morgan assigned all the section below 1692.9 m to the Cretaceous *F. longus* and *M. druggii* Zones. Clearly Early Eocene section is present and includes the swc at 1691.6 m, but deeper records are considered caving and mud contamination of the swcs in view of the Morgan (1991) data and compelling log correlation with equivalent section in Duntroon 1.

Greenly 1

Morgan and Hooker (1993a) identified two spore–pollen zones, and a single dinoflagellate zone, within the Tertiary interval 1845–2007 m in Greenly 1.

Despite poor yields at 2007 m, the frequent occurrence of the pollen *Australopollis obscurus, Lygistepollenite florinii, P. mawsonii* and *Proteacidites* spp., and the presence of dinoflagellates *Deflandrea speciosus* and *Palaeostomocystis reticulata,* support assignment to the Paleocene *L. balmei* Zone.

From 1845–1864 m, an age no older than the Lower *N. asperus* Zone is suggested in the absence of any spore–pollen indicators. The presence of the dinoflagellates *A. australicum*, *I. maculatum, Wilsonidinium* *lineidentatum, Tritonites tricornis* and *Wetzeliella echinosuturata* (1845 m) indicates the Middle Eocene Upper *A. australicum* Zone (Morgan and Hooker, 1993a), which correlates with part of the Lower *N. asperus* spore–pollen zone.

Duntroon 1

Very poor spore–pollen assemblages have been recorded in Duntroon 1 over the Tertiary interval between 1678.72–1833 m. Morgan (1986) recognised two zones: the Early Eocene middle *Malvacipollis diversus* Zone at 1789.97–1818.33 m, and the Late Eocene Middle *N. asperus* Zone at 1678.72–1686.00 m.

Assignment to the middle *M. diversus* Zone is indicated by a lack of younger indicators and the youngest occurrence of *Tricolpites gillii*. The base is defined by the oldest occurrences of *Banksieacidites elongatus*, *Proteacidites ornatus*, *Anacolosidites acutullus, Beaupreadites verrucosus* and *Triporopollenites ambiguus* (Morgan, 1986).

Assignment to the Middle *N. asperus* Zone is indicated at the base by the oldest *P. tuberculatus* and at the top by the youngest occurrence of *Proteacidites kopiensis*, abundant *P. pachypolus* (1678.72 m), *Santalumidites cainozoicus* and *Proteacidites incurvatus* (1686.0 m). The recorded presence of the dinoflagellate *Corrudinium incompositum* by Morgan (1986), in association with numerous other noted age significant dinoflagellate species, supports assignment to the *C. incompositum* Zone (Morgan, 1993).

Borda 1

In Borda 1 Morgan and Hooker (1993b) recorded Tertiary sediments from 2105 to 2375.0 m, of Early Paleocene to late Middle Eocene age, and assigned two spore–pollen and two dinoflagellate zones.

The Early Paleocene lower *L. balmei* Zone at 2375.0 m is indicated at the base by an absence of older markers and at the top by the occurrence of *Gambierina rudata* and *Tetracolporites verrucosus* without younger markers. The frequent occurrence of the dinoflagellates *D. speciosus, P. reticulata* and *Spiniferites* spp. support a Paleocene age.

Assignment to the upper *L. balmei* Zone (2210–2375 m) is indicated at the base by oldest *Proteacidites grandis* and *P. incurvatus* and at the top by youngest *G. rudata.* The dinoflagellate *Eisenackia crassitabulata* occurs over this interval, indicating the Paleocene *E. crassitabulata* Zone.

The *Deflandrea heterophlycta* dinoflagellate zone (2120.0–2143.0 m) of late Middle Eocene age is indicated by the presence of *D. heterophlycta* in the absence of younger markers and in association with *D. phosphoritica*, *A. australicum* and *Tritonites spinosus*. Morgan and Hooker (1993b) correlate this zone with the Lower *N. asperus* spore–pollen zone.

Foraminifera

Zonation

Two foraminiferal zonal schemes have been used to subdivide the Tertiary succession overlying the Bight Basin, namely that of Taylor (1966 and subsequent revisions, e.g., Taylor, 1975c, 1977a, b), and that of Ludbrook and Lindsay (1969), modified by McGowran et al. (1971). Both are based on planktonic foraminifera. The former was developed for the Victorian succession, the latter for the South Australian. Both schemes have been used successfully for local, regional and inter-regional correlation (e.g. Apthorpe, 1972a, b; Taylor, 1975b). However, datum recognition is now the generally accepted method of foraminiferal dating and correlation in SE Australia. These have been correlated with the standard P and N planktonic foraminiferal zones developed for the tropics. This correlation has been possible largely by adopting the sequence stratigraphic approach of McGowran and others (e.g., McGowran, 1991; McGowran et al., 1992; McGowran and Li, 1993). The foraminiferal events recognised in southern Australia for which correlation with the P and N zones has been possible, together with others recognised in the high latitudes, are summarised in Figure 5.4.

Wells

Planktonic foraminiferal data is reviewed on the same well-by-well basis used above and data is reinterpreted in terms of P and N zones by correlating last and first downhole occurrences with equivalent first and last appearance datums (foraminiferal events) respectively (Fig. 5.4). In most cases, the sampling and/or fauna present have allowed ages to be interpreted only as within a range of zones (e.g. between P15 and P17). The zonal interpretations for each well are discussed below and summarised in Figure 5.5 and Appendix 5.1.

Western Bight Basin: Eyre Sub-basin

Jerboa 1

In Jerboa 1 Conley (1980) recorded planktonic foraminifera from 26 closely spaced swc samples between 1020 and 1135 m, as well as from cuttings samples between 1020 and 1030 m. The distance between samples range from 1.5 to 7 m, with most being 5 m apart.

The range chart provided by Conley (1980) includes a number of inconsistencies in the stratigraphic ranges presented for key species. In particular, the overlap in the occurrence of *Subbotina angioporoides minima* with *Turborotalia euapertura* (1020–1027 m) and with *Turborotalia ampliapertura* (1020–1085 m) is anomalous. The overlap in stratigraphic range of *S. angioporoides* and *A. primitiva* between 1080 and 1101 m, and of *Tr. ampliapertura* and *A. primitiva* between 1080 m and 1085 m need explaining, as does the range of *S. frontosa* and *Praetenuitella insolita* between 1102.5 and 1115 m.

Since all these taxa are recorded from swcs, incorrect identification of one or more of the species seems likely. Re-examination of the original material would probably resolve

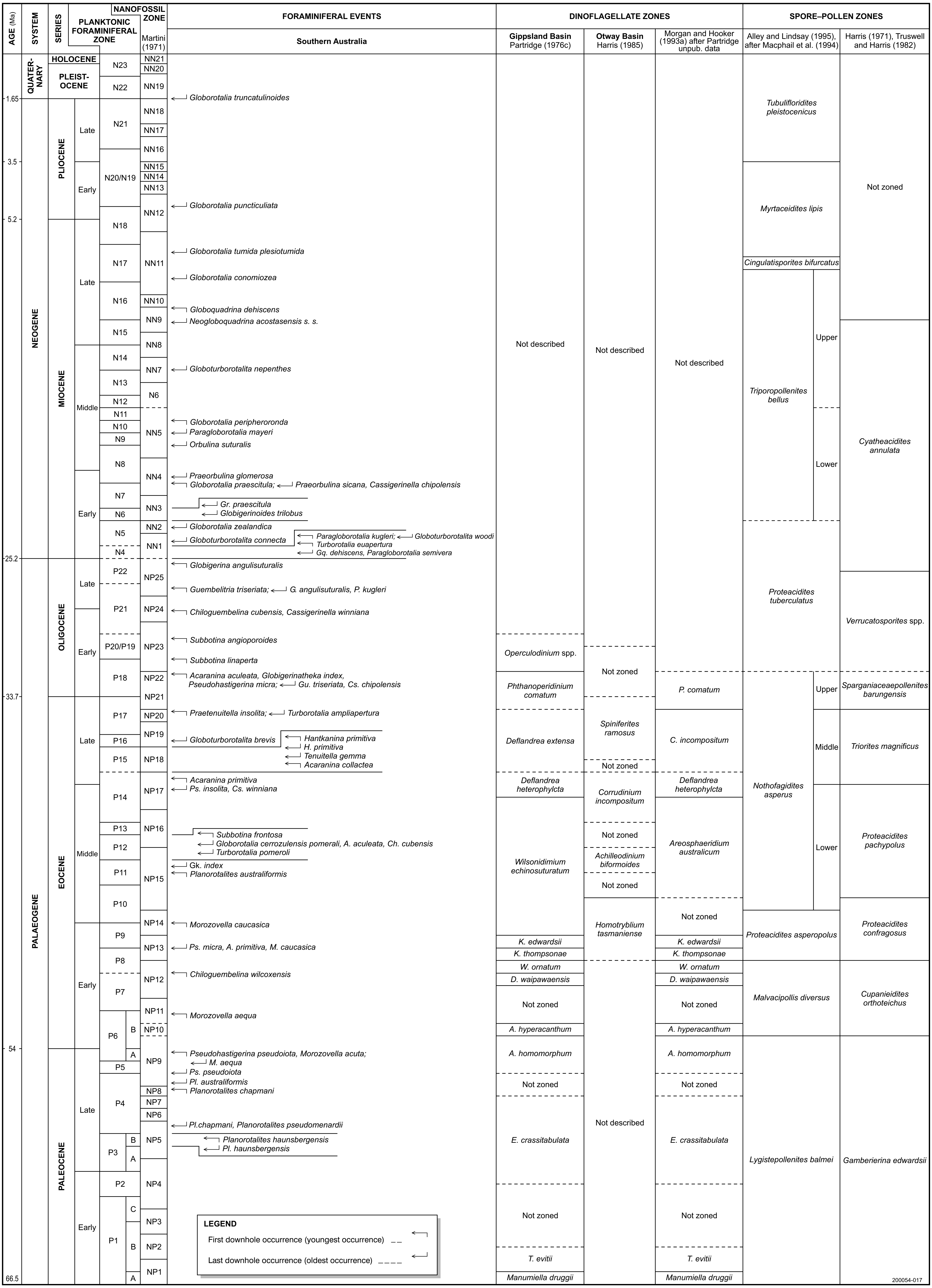


Figure 5.4 Tertiary biostratigraphic zonation of the portion of the Eucla Basin overlying the Bight Basin and Tertiary foraminiferal events recognised in southern Australia. (After Morgan et al. (1995); nanofossil zonations after Berggren et al. (1995).)

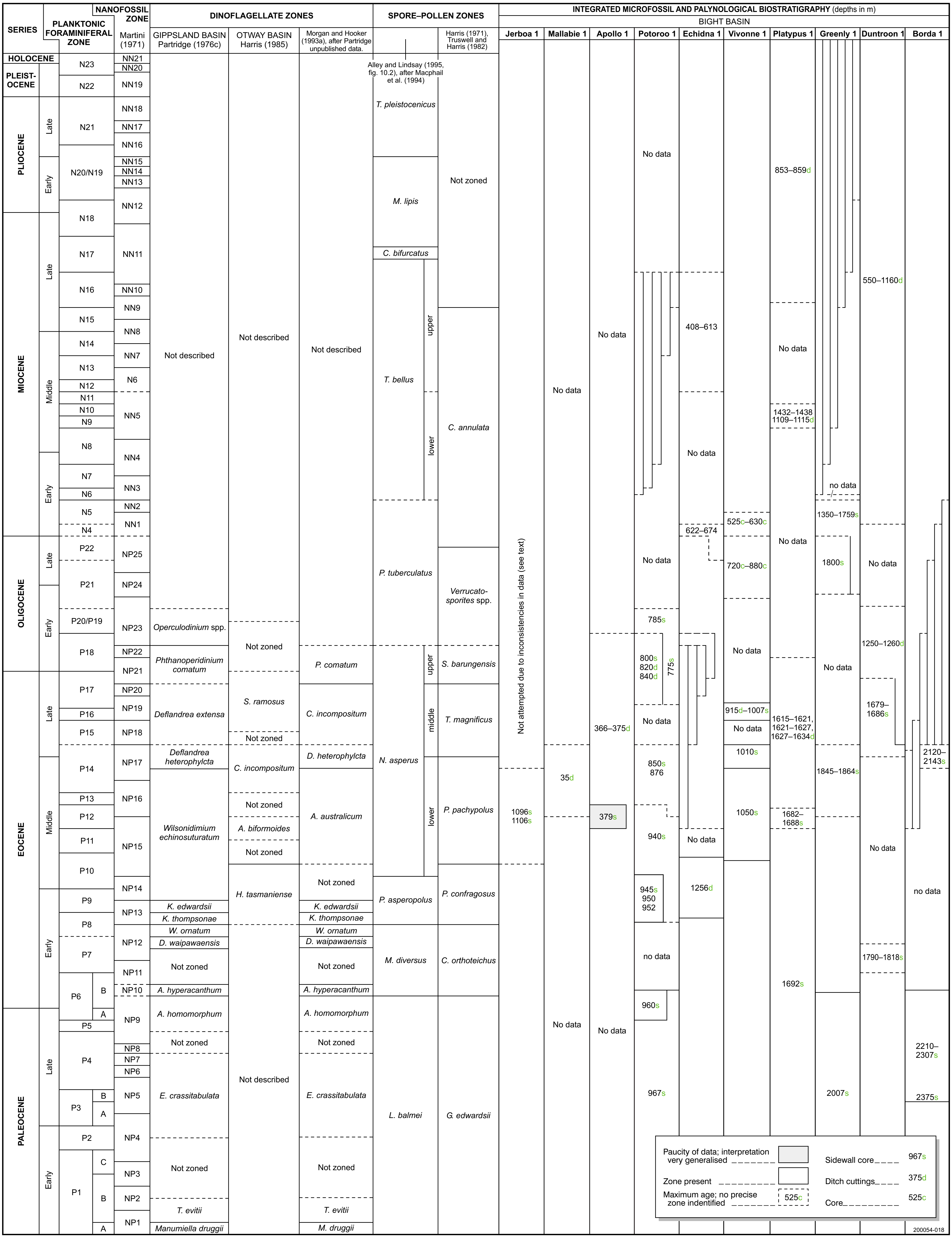


Figure 5.5 Intregrated microfossil and palynological Tertiary biostratigraphy of wells penetrating the Eucla and Bight Basins.

these discrepancies. Because of the inadequacies in the data, no attempt has been made to interpret the planktonic foraminiferal zones in this well.

North–central Bight Basin: Madura Shelf

Mallabie 1

Lindsay and McGowran (Harris et al., 1969) examined selected cuttings samples from Mallabie 1, supplemented by sludges from the adjacent Mallabie water well. Planktonic foraminifera were reported from two samples. At 189–191 m, the occurrence of *Truncorotaloides* af. *topilensis* is caved and not zone diagnostic. At 35 m, the presence of *Chiloguembelina cubensis* and *Acarinina primitiva* indicate an age between late P12 and P14.

Apollo 1

Taylor (1975a) examined one swc from 379 m and four cuttings samples from the Tertiary section in Apollo 1. The cuttings samples represent 9 m intervals between 366 and 402 m. The only planktonic foraminifera recorded were from cuttings at 366–375 m and swc at 379 m. The younger assemblage includes *Subbotina linaperta* and *Globigerinatheka index*, indicative of an age between P12 and P18. The presence of *S. linaperta* and *Subbotina frontosa* in the swc provides evidence of P12 aged strata.

Central Bight Basin: central Ceduna Sub-basin

Potoroo 1

Taylor (1975b) reported planktonic foraminifera from 16 swcs and eight cuttings samples between 576 m and 960 m in Potoroo 1. Samples were between 1 and 87 m apart, with most less than 10 m apart. The oldest strata recorded are dated as being P6 in age, based on presence of *Pseudohastigerina pseudoiota* at 960 m.

The youngest sample (576 m) includes *Globorotalia peripheroronda*, a species whose range is inconsistent with two other species from this sample, namely *Globigerina nepenthes* and *Globorotalia miotumida miotumida*. *Gr. peripheroronda* is not known above N10, while *G. nepenthes* and *Gr. miotumida miotumida* first appear in N14 and N16 respectively. Since these species are from a swc, it seems likely that at least one of them is identified incorrectly. *Gr. peripheroronda* and *Gr. miotumida miotumida* are recorded with certainty only from this sample (they are both tentatively identified from 693 m). Each were identified from no more than 20 specimens. In contrast, *G. nepenthes* was recorded from two samples (576 m and 583 m). Its identification was based on a larger number of specimens (more than 20 from 576 m). The original material needs to be re-examined, but based on the greater numbers of specimens of *G. nepenthes*, it seems likely that this is identified correctly. Since the co-occurrence of *G. nepenthes* and *Gr. miotumida miotumida* poses no problem in terms of age interpretation, *Gr. miotumida miotumida* is probably also identified correctly. Consequently, the youngest strata are tentatively dated as N16, based on the presence of *Gr. miotumida miotumida* and *Globoquadrina dehiscens*.

Taylor (1975b) interpreted three unconformities in this well. The oldest of these, tentatively identified between 940 and 945.5 m, was based on a 'dislocation of faunal sequence' and was regarded as corresponding to an abrupt change in lithology from 'greensand' to the transgressive marine sequence. A break in sedimentation at this depth is consistent with the reinterpreted age data herein (i.e. P6 at 960 m, and between P8 and ?P12 at 940 m).

The unconformity identified between 840 and 850 m (Taylor, 1975b, encl. A) also seems to be verified by the reinterpreted foraminiferal data. The foraminiferal assemblage in the swc at 850 m records an age between late P12 and P14, based on *Tenuitella aculeata* and *A. primitiva*. At 840 m (cuttings) the presence of *Tr. ampliapertura* below *S. linaperta* indicates an age between P17 and P18. It may be significant that this break corresponds at least approximately with the sequence boundary recognised globally at the base of the TA4 supercycle.

The youngest unconformity separates strata at 775 m (swc) aged between P17 and P20, based on the presence of *S. angioporoides* above *Tr. ampliapertura*, and those at 770 m (cuttings) dated as N6 or younger, on the presence of *Globigerinoides trilobus*.

EASTERN BIGHT BASIN: DUNTROON AND EASTERN CEDUNA SUB-BASINS

DUNTROON SUB-BASIN

Echidna 1

Apthorpe (1972b) recorded planktonic foraminifera in Echidna 1 from 31 cuttings samples ranging from 408 to 1216 m. Samples were taken up to 40 m apart, but generally between 12 and 27 m apart. The oldest strata are dated between P12 and P18, based on *S. linaperta* below *G. index*. The youngest strata are dated as N6–N16, based on occurrence of *Gq. dehiscens* above *Gs. trilobus* at 613 m. There is no evidence of any stratigraphic breaks in the succession, but there is no age data between 622 m dated as P22 – c. N4 (based on *Globorotalia kugleri*), and 613 m dated as N6–N16.

Vivonne 1

In Vivonne 1 Rexilius and Powell (1994b) recorded planktonic foraminifera from 10 cuttings samples between 525 and 960 m, all less than 55 m apart. The only ages that can be assigned to sediments in this well are ?P15–P18 (based on *S. ?angioporoides* and *S. linaperta*) at 915–960 m, and about the P22–N4 boundary (based on *Globigerina woodi* and *T. euapertura*) at 720–880 m. It is possible that an unconformity exists between 915 m and 880 m, but no samples were submitted for biostratigraphic analysis and the missing zones could be accommodated in the 35 m of intervening, undated sediment.

EASTERN CEDUNA SUB-BASIN

Platypus 1

Apthorpe (1972a) recorded planktonic foraminifera from 15 cuttings samples between 488 and 1688 m in Platypus 1. Each sample represents 6 m of sediment and samples are up to 122 m apart. The oldest strata are P12 in age, based on the occurrence of *S. linaperta* below *S. frontosa* at 1682–1688 m. The youngest strata are N16 or younger, based on the occurrence of *Globorotalia menardii miotumida* at 853–859 m. A possible unconformity occurs between 1438 and 1609 m. Strata at 1438 m are dated as between N9 and N10, while those at 1609 m are between P12 and ?P18;. however it is possible that the intervening zones are represented by the 171 m of undated sediments between.

It is noteworthy that in the interval 1646–1843 m, palynological data indicate an age older than that interpreted from the foraminifera — namely Early Eocene and Late Cretaceous compared with P12 or younger. Since the foraminiferal dates are all from cuttings, these are considered caved.

Greenly 1

Rexilius and Powell (1994a) recorded planktonic foraminifera from 13 swcs in Greenly 1. The oldest strata are dated as N6 or younger, based on the presence of *Gs. trilobus*. The youngest strata are tentatively dated as about the N19–N20 boundary, based on the occurrence of a form identified as *'Globorotalia puncticulata/ Gr. conomiozea'*. This interpretation is inconsistent with the occurrence of *Gq. dehiscens* (not known above N16) at 610 m. Re-examination of the original material is necessary, but it is possible that the range of *Gq. dehiscens* extends into younger strata than previously supposed.

Duntroon 1

In Duntroon 1 planktonic foraminifera were identified from two cuttings samples (Taylor, 1986). At 1250–1260 m, the presence of *S. angioporoides* indicates a P15–P20 age. At 550–560 m, *Globigerina woodi connecta* indicates an age of N5 or younger.

Borda 1

In Borda 1 Rexilius and Powell (1993) recorded planktonic foraminifera from 31 swcs ranging in depth from 625 to 2135 m. The oldest strata are dated as P12 – c. P15 based on the presence of *S. linaperta* below *S. angioporoides minima* at 2135 m. The age of the youngest strata is probably about the N16–N17 boundary, based on the occurrence of *Gq. dehiscens* above *Gr. conomiozea* at 625 m. The age of the intervening strata is confused due to the identification of a number of taxa with conflicting ranges. Specifically, *Globorotalia praescitula* (not known above N7) is reported at 1020 m together with *Praeorbulina glomerosa circularis* (N9 or younger). A similar discrepancy arises from the occurrence at 850 m of *Gr. menardii miotumida* (N15 or younger) below *Gr. peripheroronda* (800 m; not known above N10). Re-examination of the original material is necessary. Based on the nanofossil data available for this well (App. 5.1) it seems likely that *Pr. glomerosa circularis, Gr. praescitula* and *Gr. menardii miotumida* are identified incorrectly.

Nanofossils

The only zonation to which nanofossils from the Tertiary overlying the Bight Basin have been referred to is that of Martini (1971), Fig. 5.4. Nanofossil zones have been recognised in the Greenly 1, Borda 1 and Vivonne 1 wells (Rexilius and Powell, 1994a, 1993, 1994b). These are summarised in Appendix 5.1.

Ages based on foraminifera and those interpreted from nanoplankton are consistent, except in Vivonne 1. There, the age of the sediments between 720 and 880 m based on foraminifera (c. P22–N4 boundary) is slightly younger than that based on nanofossils (NP24 and NP25). Since these ages are based on cuttings, it is likely that the older age is correct, and that the foraminifera are caved.

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APPENDIX 5.1
Foraminiferal datums, nanofossil zones and interpreted ages

Apollo 1 foraminiferal datums and interpreted ages

Depth (ft)	**Depth** (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**
1200–1230	366–375	Cuttings	LAD *S. linaperta*	P18	Between P12 & P18
			LAD *G. index*	basal P18	
1244	379	Swc	FAD *S. linaperta*	P12	P12
			LAD *S. frontosa*	P12	
			FAD *P. micra*	P9	
			LAD *P. micra*	basal P18	
			?FAD *G. index*	?P12	

Borda 1 foraminiferal datums, nannofossil zones and interpreted ages

Depth (m)	Sample type	Datums	Datum equivalent planktonic foraminiferal zones	Interpreted planktonic foraminifera zones	Nannofossil zone (Rexilius & Powell, 1993)	Integrated biostratigraphy	
						Planktonic foraminiferal zones	**Nannofossil zones**
625	Swc	FAD *G. trilobus*	N6	Probably about the N16/N17 boundary	NN15 or older	Probably about the N16/N17 boundary	Probably NN11
700	Swc	LAD *G. dehiscens*	N16				
		FAD *G. nepenthes*	N14				
750	Swc	FAD *G. conomiozea*	N17				
800	Swc	LAD *G. peripheroronda*	N10	Not attempted owing to inconsistencies in data (see text for discussion).	Between NN1 & NN6	Between lower N4 & lower N13	Between NN1 & NN6
850	Swc	FAD *G. miotumida*	N15				
		FAD *O. universa*	N9				
930	Swc	LAD *G. praescitula*	N7				
960	Swc	FAD *G. woodi*	top N4		Between NN1 & NN5	Between N4 & N11	Between NN1 & NN5
990	Swc	FAD *P. glomerosa*	N8				
		FAD *P. glomerosa curva*	N8				
1020	Swc	FAD *G. praescitula*	N6		NN1	N4 or N5	NN1
		FAD *P. glomerosa circularis*	N9				
		FAD *G. dehiscens*	N4				
1051	Swc	LAD *G. labiacrassata*	N4	Ca N4/N5 boundary		ca N4/5 boundary	
		FAD *G. woodi connecta*	N5				
1167	Swc			Between P15 & ca N4/N5 boundary			
1210.5	Swc				NN1 & NP25/24	Between P15 & ca N4/N5 boundary	Between NN1 & NP25/24
1240	Swc				NP23 or older	Between P15 & lower P21	Between NP18 & NP23
1270	Swc				NP22 or older	Between P15 & P18	Between NP18 & NP22
1573	Swc				NP22 or older		
1603	Swc	LAD *S. linaperta*	P18	Between P15 & P18	NP16 to NP19	Between P15 & P18	Between NP18 & NP 19
1892	Swc	LAD *S. angioporoides*	P20				
		LAD *P. micra*	P18				
		FAD *S. angioporoides*	P15				
		FAD *P. micra*	P9				
1985	Swc	LAD *S. angioporoides minima*	ca P15	Between P12 & P15		Between P12 & P15	Between NP16 & NP18
		FAD *S. angioporoides minima*	P11				
2135	Swc	FAD *S. linaperta*	P12				

Duntroon 1 foraminiferal datums and interpreted ages

Depth (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**
550–1160	Cuttings	FAD *G. woodi connecta*	N5	N5 or younger
1250–1260	Cuttings	FAD *G. angioporoides*	P15	Between P15 & P20
		LAD *G. angioporoides*	P20	

Echidna 1 foraminiferal datums and interpreted ages

Depth (ft)	**Depth** (m)	**Sample type**	**Datums**	**Datum equivalent planktonic foraminiferal zones**	**Interpreted planktonic foraminifera zones**
1340–1350	408–411	Cuttings	LAD *G. dehiscens*	N16	Between N6 & N16
			FAD *G. ruber*	N5	
1600–1610	488–491	Cuttings	FAD *G. dehiscens*	N4	
1700–1710	518–521	Cuttings	FAD *G. woodi*	N4	
2000–2010	610–613	Cuttings	FAD *G. trilobus*	N6	
2040–2050	622–625	Cuttings	LAD *Gr. Kugleri*	ca N4	Between P22 & ca N4
2200–2210	671–674	Cuttings	FAD *Gr. kugleri*	P22	
3200–3210	975–978	Cuttings	LAD *G. labiacrassata*	basal P22	Between P17 & basal P22
			LAD *G. euapertura*	N4	
3330–3340	1015–1018	Cuttings	LAD *G. ampliapertura*	P20	Between P17 & P20
			LAD *S. angioporoides*	P20	
3420–3430	1042–1045	Cuttings	LAD *S. linaperta*	P18	Between P17 & P18
3600–3610	1097–1100	Cuttings	LAD *G. index*	basal P18	Between P17 & basal P18
3750–3760	1143–1146	Cuttings	FAD *G. ampliapertura*	P17	
3870–3780	1180–1152	Cuttings	LAD *S.angioporoides minima?*	P11	Between P15 & P18*
			FAD *G. euapertura*	P15	
			FAD *G. ouachitaensis*	ca P12	
3880–3890	1183–1186	Cuttings	FAD *S. angioporoides*	P15	
3950–3960	1204–1207	Cuttings	FAD *S.angioporoides minima?*	P11	Between P12 & P18
3980–3990	1213–1216	Cuttings	FAD *G. index*	ca P11	
			FAD *S. linaperta*	P12	

* The tentative identification of *S. angioporoides minima* is regarded here as incorrect, based on inconsistent age ranges of associated species.

Greenly 1 foraminiferal datums, nannofossil zones and interpreted ages

Depth (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**	**Nannofossil zones** (Rexilius & Powell, 1994a)
610	Swc	LAD *G. dehiscens*	N16	?N19/20 or younger*	
690	Swc	FAD *G. puncticulata/conomiozea*	?N19/20		
733	Swc	FAD *G. conomiozea*	N17	N17 or younger*	
853.5	Swc	FAD *G. ruber*	N5	N16 or younger*	
910	Swc	FAD *G. miotumida miotumida*	N16		
956.5	Swc	FAD *G. bisphericus*	N7	N9 or younger	
		FAD *G. praemenardii*	N8		
		FAD *O. universa*	N9		
1008.5	Swc	FAD *G. dehiscens*	N4	N8 or younger	
		FAD *P. glomerosa*	N8		
1179.5	Swc	FAD *G. woodi woodi*	N5	N6 or younger	
1309	Swc	FAD *G. woodi connecta*	N5		
		FAD *G. trilobus*	N6		
1350	Swc				Between NN1 & NP24
1759	Swc				
1800	Swc				Between NP24 & NP25
1864	Swc				Between NP16 & NP19

* These interpretations are inconsistent with LAD *G. dehiscens* at 610 m (see text for discussion)

Jerboa 1 foraminiferal datums and interpreted ages

Depth (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**
1020	Swc	LAD *S. linaperta*	P18	Not attempted owing to inconsistencies in data (see text for discussion).
		LAD *S. angioporoides minima*	?P15	
		LAD *Ch. Cubensis*	mid P21	
		LAD *G. ampliapertura*	ca P20	
		LAD *G. euapertura*	P22	
1027	Swc	LAD S. angioporoides	P20	
		FAD *G. euapertura*	P16	
1070	Swc	LAD *G. index*	basal P18	
		LAD *P. micra*	basal P18	
1080	Swc	LAD *A. primitiva*	P14	
1085	Swc	FAD *G. ampliapertura*	top P17	
1090	Swc	LAD *T. insolita*	P17	
1096	Swc	FAD *Ch. Cubensis*	P12	
1101	Swc	FAD *P. micra*	P9	
		FAD *S. angioporoides*	P15	
1102.5	Swc	LAD *S. frontosa*	P12	
		FAD *G. index*	ca P11	
		FAD *S. angioporoides minima*	P11	
1115	Swc	FAD *T. insolita*	P14	
1133	Swc	FAD *S. linaperta*	P12	
1135	Swc	FAD *A. primitiva*	P9	
		?FAD *S. linaperta*	?P12	

Mallabie 1 foraminiferal datums and interpreted ages

Depth (ft)	**Depth** (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**
116	35	Cuttings	FAD *A. primitiva*	P9	Between upper P12 & P14
			LAD *A. primitiva*	P14	
			FAD *G. index*	ca P12	
			LAD *G. index*	Basal P18	
			FAD *P. micra*	P9	
			LAD *P. micra*	Basal P18	
			FAD *C. cubensis*	Upper P12	
			LAD *C. cubensis*	Mid P21	

Platypus 1 foraminiferal datums and interpreted ages

Depth (ft)	**Depth** (m)	**Sample type**	**Datums**	**Datum equivalent planktonic foraminiferal zones**	**Interpreted planktonic foraminifera zones**
2800–2820	853–859	Cuttings	FAD *G. menardii miotumida*	N16	N16 or younger
3640–3660	1109–1115	Cuttings	LAD *G. peripheroronda*	N10	N9–N10
4700–4720	1432–1438	Cuttings	FAD *G. dehiscens*	N4	
			LAD *G. dehiscens*	N16	
			FAD *O. universa*	N9	
			FAD *G.* cf. *nepenthes*	?N14	
			FAD *O. suturalis*	N9	
5280–5300	1609–1615	Cuttings	LAD ?*G. index*	?basal P18	P12–?P18
5300–5320	1615–1621	Cuttings	LAD *S. linaperta*	P18	ca P12–basal P18
			LAD *G. index*	basal P18	
5320–5340	1621–1627	Cuttings	FAD *G. index*	ca P12	
5340–5360	1627–1634	Cuttings	FAD ?*G. index*	?ca P12	
5480–5500	1670–1676	Cuttings	LAD *A. primitiva*	P14	P12
			LAD *S. frontosa*	P12	
5500–5520	1676–1682	Cuttings	LAD *P. micra*	basal P18	
5520–5540	1682–1688	Cuttings	FAD *P. micra*	P9	
			FAD *A. primitiva*	P9	
			FAD *S. linaperta*	P12	

Potoroo 1 foraminiferal datums and interpreted ages

Depth (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**
576	Swc	FAD *O. universa*	N9	?N16*
		FAD *O. suturalis*	N9	
		FAD *P. glomerosa circularis*	N8	
		FAD *G. miotumida miotumida*	N16	
		LAD *G. peripheroronda*	N10	
		LAD *G. dehiscens*	N16	
583	Swc	FAD *G. nepenthes*	N14	?Between N14 & N16*
605		?FAD *G. nepenthes*	?N14	?Between N8 & N16
		FAD *P. glomerosa curva*	N8	
693	Swc	?FAD *G. miotumida miotumida*	?N16	
		FAD *P. glomerosa*	N8	
700	Swc	FAD *Gs. rubra*	N5	Between N8 & N16
717	Swc	FAD *G. menardii praemenardii*	N8	
760	Cuttings	FAD *G. dehiscens*	N4	Between N7 & N16
		FAD *G bisphericus*	N7	
		FAD *G. woodi connecta*	N5	
770	Cuttings	FAD *G. woodi woodi*	top N4	Between N6 & N16
		FAD *G. trilobus*	N6	
775	Swc	LAD *G. euapertura*	P22	Between P17 & P20
		LAD *S. angioporoides*	P20	
785	Swc	FAD *G. brevis*	P16	
800	Swc	LAD *G. ampliapertura*	P20	Between P17 & P18
		LAD *S. linaperta*	P18	
820	Cuttings	FAD *T. gemma*	P15	
840	Cuttings	FAD *G. euapertura*	upper P15	
		FAD *S. angioporoides*	P15	
		FAD *G. ampliapertura*	P17	

Vivonne 1 foraminiferal datums, nannofossil zones and interpreted ages

Depth (m)	**Sample type**	**Datums**	**Datum equivalent planktonic zone**	**Interpreted planktonic foraminifera zone**	**Nannofossil zones** (Rexilius & Powell, 1994b)	**Integrated biostratigraphy**	
						Planktonic foraminiferal zones	**Nannofossil zones**
525–530	Cuttings				NN1	Between N4 & early N5	NN1
625–630	Cuttings						
720–725	Cuttings	FAD *G. euapertura*	P15	Ca P22/N4 boundary	NP25 & 24	Minor discrepancy between foram and nannofossil data	Minor discrepancy between foram and nannofossil data
		LAD *G. euapertura*	P22				
875–880	Cuttings	FAD *G. woodi*	N4				
915–920	Cuttings	LAD *S. ?angioporoides*	?P20	Between ?P15 & P18	NP19	P16	NP19
		LAD *S. linaperta*	P18				
955–960	Cuttings	FAD *S. ?angioporoides*	?P15				
		FAD *S. linaperta*	P12				
1007	Swc						
1030	Swc				NP16 & 17	Between early P12 & P14	NP 16 & 17